COVER SHEET

AAA FAX

To: Jack Weber, AAA Mid-Atlantic

Fax #: 215-568-1153

Subj: Responding to that Pechan Analysis of AAA's "Clearing The Air" Study

Date: May 29, 1996

Pages: 4, including this cover sheet.

COMMENTS:

As you requested on Friday, here is a response from EEA on the Pechan analysis (for PennDER) on the "Clearing The Air" study.

EEA continues to back its original emission inventory percentages and sees no reason to change them.

RECEIVED

MAY 29 1996

J. W.. Jr.

From the desk of...

William Berman
Director, Federal Relations
AAA
1440 NY Ave., NW Suite 200
Washington DC 20005

202-942-2056
Fax: 202-783-4788

	A	B	C	D	E	F
1	DATA AS REPORTED TO EEA BY STATES:					
2						
3	1990 VOC:					
4				NJ	Pa	Total
5						
6						
7	Point	Major Point		146	175	321
8	Area	Minor Point		61		
9		Other Area		34	226	321
10	On-Highway			108	188	296
11	Off-Highway			42	91	133
12						
13	All Sources			391	680	1071
14						
15						
16						
17						
18						
19						
20						
21						
22						
23	1990 NOx:					
24				NJ	Pa	Total
25						
26						
27	Point	Major Point		310	157	467
28	Area	Minor Point		5		
29		Other Area		3	54	62
30	On-Highway			132	157	289
31	Off-Highway			40	78	118
32						
33	All Sources			490	446	936
34						
35						
36						
37						
38						
39						
40						

I	J	K	L	
DATA USED BY EEA FOR AAA REPORT:				
		Total	Pct.	Pechan
Point		321	30.0%	
Area		321	30.0%	
LDV		165	15.4%	26%
LDT		84	7.8%	6%
HDV+MC		47	4.4%	
Off-Highway		133	12.4%	
All Highway		296	27.6%	
All Sources		1071	100.0%	
Point+Area		642	59.9%	51%
LDV		165	15.4%	26%
LDT		84	7.8%	6"
Other Mobile		180	16.8%	1"
		Total	Pct.	
Point		468	49.9%	
Area		62	6.6%	
LDV		110	11.7%	18%
LDT		52	5.5%	4%
HDV+MC		127	13.6%	
Off-Highway		118	12.6%	
All Highway		289	30.8%	
All Sources		937	100.0%	
Point+Area		530	56.6%	57%
LDV		110	11.7%	18%
LDT		52	5.5%	4%
Other Mobile		245	26.1%	21%

EMISSION CONTROL STANDARDS FOR PASSENGER CARS

(GRAMS PER MILE)

YEAR	CO	NOX	HC
1960	84.0	4.1	10.6
1968	51.0		6.3
1970	34.0		4.1
1972	28.0		3.0
1973		3.1	
1975	15.0	3.1	1.5
1977		2.0	
1980	7.0		.41
1981	3.4	1.0	
1994		.40	.25*
2003	1.7	.2	.125*

*=NMHC

EXAMPLES OF EMISSIONS FROM NEW NONROAD EQUIPMENT RELATIVE TO A TYPICAL IN-USE PASSENGER CAR

1 Hour of use	Pollutant	Car miles
1 Riding mower	VOC	= 20
1 Garden tiller	VOC	30
1 Garden tractor	VOC	30
1 Shredder	VOC	30
1 Generator set	VOC	40
1 Lawnmower	VOC	50
1 String trimmer	VOC	70
1 Leaf blower	VOC	100
1 Chain saw	VOC	200
1 Outboard motor	VOC	800
1 Forklift	NOx	250
1 Agricultural tractor	NOx	500
1 Construction crane	NOx	600
1 Farm combine	NOx	850
1 Crawler tractor	NOx	900

EPA - Region III
handout at 1996 Flower Show

Information Requests

COMSIS PRESENTATION
ON MOBILE EMISSIONS

May 15, 1996

1. a. VOC & NOx changes with speed changes.
   b. Emissions changes from idle to traveling.

2. NOx emissions from Heavy Duty Diesel Trucks.

3. Benefits from traffic signal synchronization.

4. Emissions benefits from land use controls.

5. I/M Program Overview

GENERAL ASSUMPTIONS

Areas/Counties Covered

Bucks
Chester
Delaware
Montgomery
Philadelphia

Year Analyzed

1996

Mobile5a_H Assumptions

1993 Vehicle Registration Distributions as provided by PennDOT Bureau of Motor Vehicles

National default vehicle registration distribution for Heavy Duty Diesel Vehicles (HDDV)

Typical Ozone Season Day (July 1st)

Reformulated Gasoline for the 5-county area

Inspection and Maintenance Program (I/M) Parameters vary by the scenario analyzed based on Pennsylvania's proposed I/M program and EPA's high performance standard

Inspection and Maintenance Program Scenarios

1996 scenario with Pennsylvania proposed I/M program (with 50% credit)

1996 scenario with EPA High Performance Standard

Travel Estimation Assumptions

VMT and mix estimates are based on PennDOT Roadway Management System (RMS) and Highway Performance Management System (HPMS) data

All travel estimates are aggregated by county, area type, facility type, and vehicle type through the post processor for air quality (PPAQ)

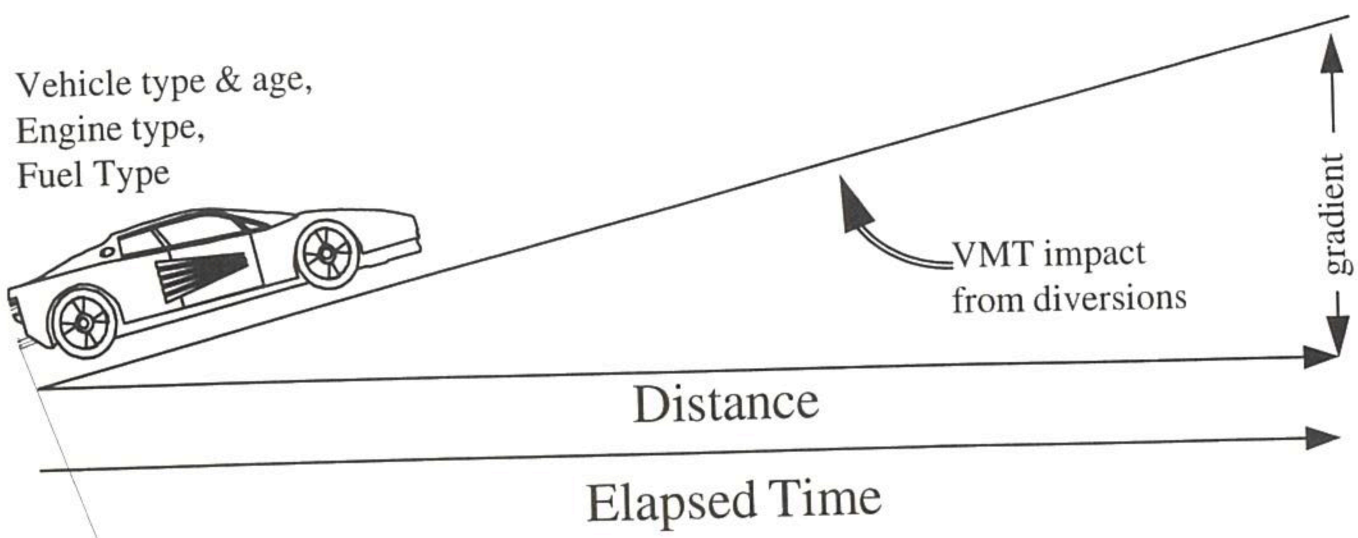
Total Emissions are calculated through PPAQ and MOBILE5a_H

GLOSSARY OF ACRONYMS

ATMS	Automated Traffic Management Systems
CO	Carbon Monoxide
EPA	U.S. Environmental Protection Agency
HDDV	Heavy Duty Diesel Trucks (>9,000 lbs)
HDGV	Heavy Duty Gas Trucks (>9,000 lbs)
HPMS	Highway Performance Management System
KG	Kilograms
LDDV/T	Light Duty Diesel Vehicles and Trucks (<9,000 lbs)
LDGT	Light Duty Gas Trucks (<9,000 lbs)
LDGV	Light Duty Gas Vehicles
LOS	Level of Service
MC	Motorcycles
NOx	Oxides of Nitrogen
PaDEP	Pennsylvania Department of Environmental Protection
PennDOT	Pennsylvania Department of Transportation
PPAQ	Post Processor for Air Quality
RFG	Reformulated Gasoline
RMS	Roadway Management System
TPD	tons per day
VOC	Volatile Organic Compounds

Drive Cycle Impacts on Emissions

Idle	Acceleration	Cruise	Deceleration	Idle

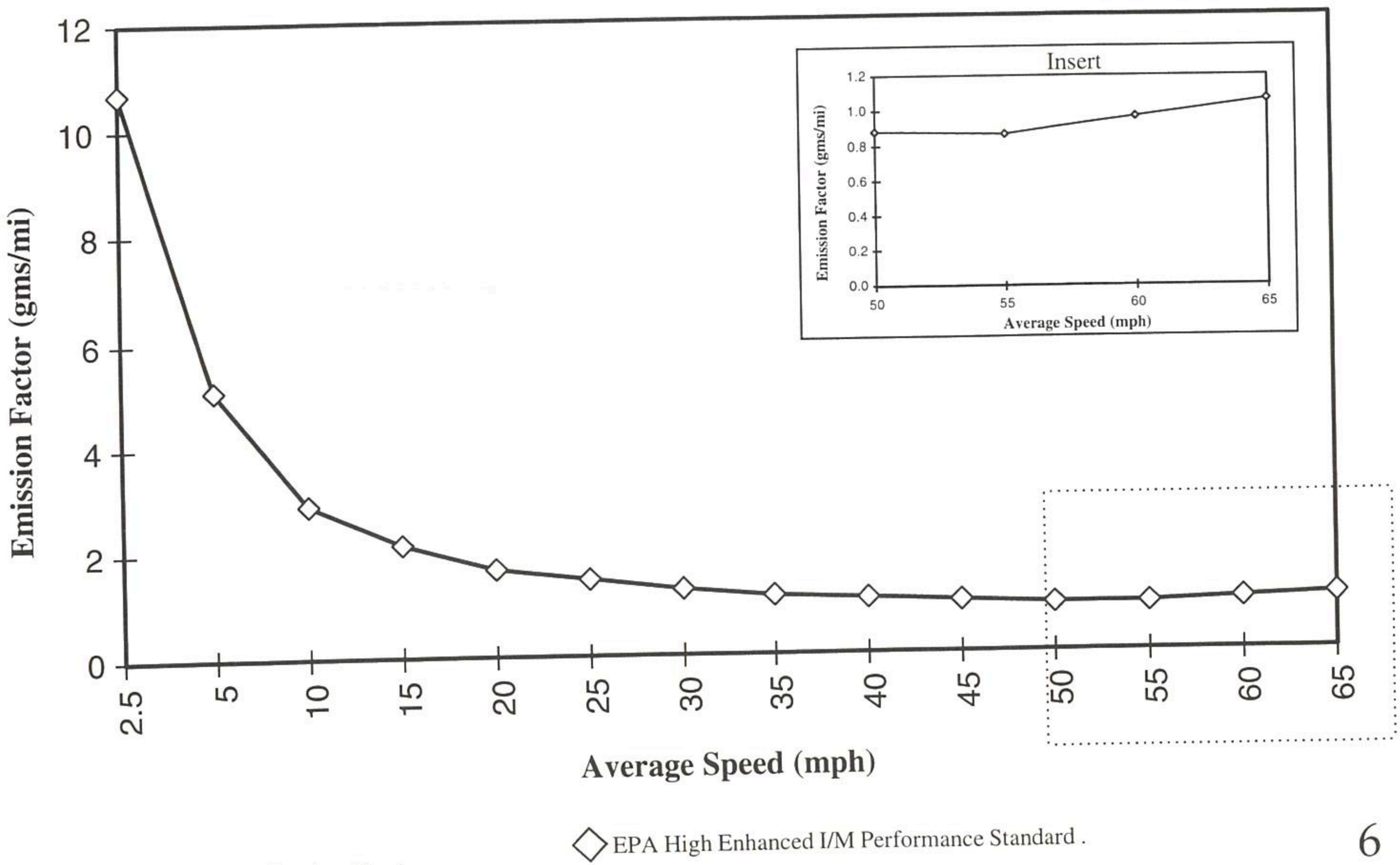


Question 1.a

How do NOx and VOC emissions from automobiles change with changes in speed?

1996 Philadelphia, PA - VOC Emissions Curve

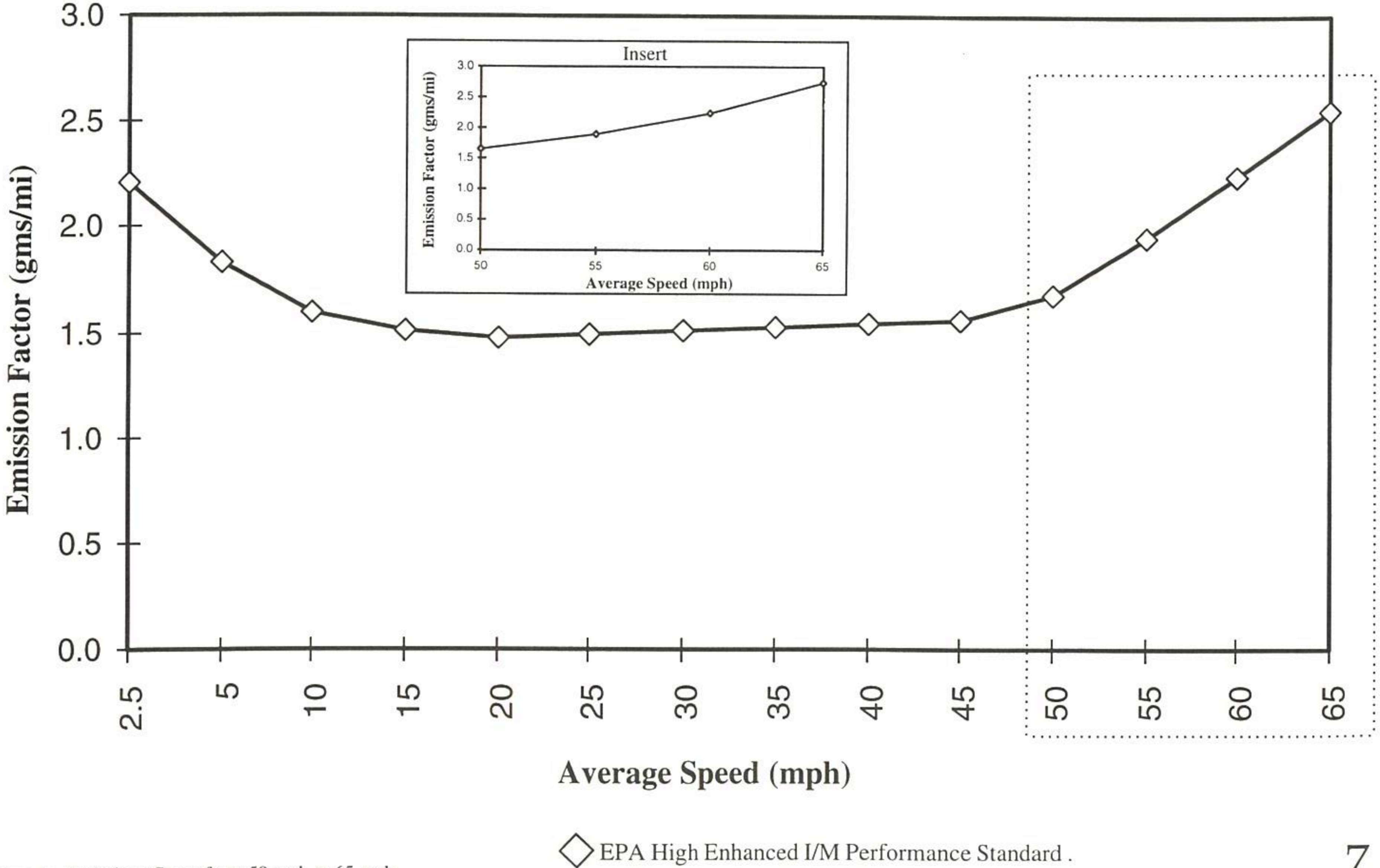
5-County Area Composite Emission Factors



Insert : F s Curve from 50 mph to 65 mph

1996 Philadelphia, PA - NOx Emissions Curve

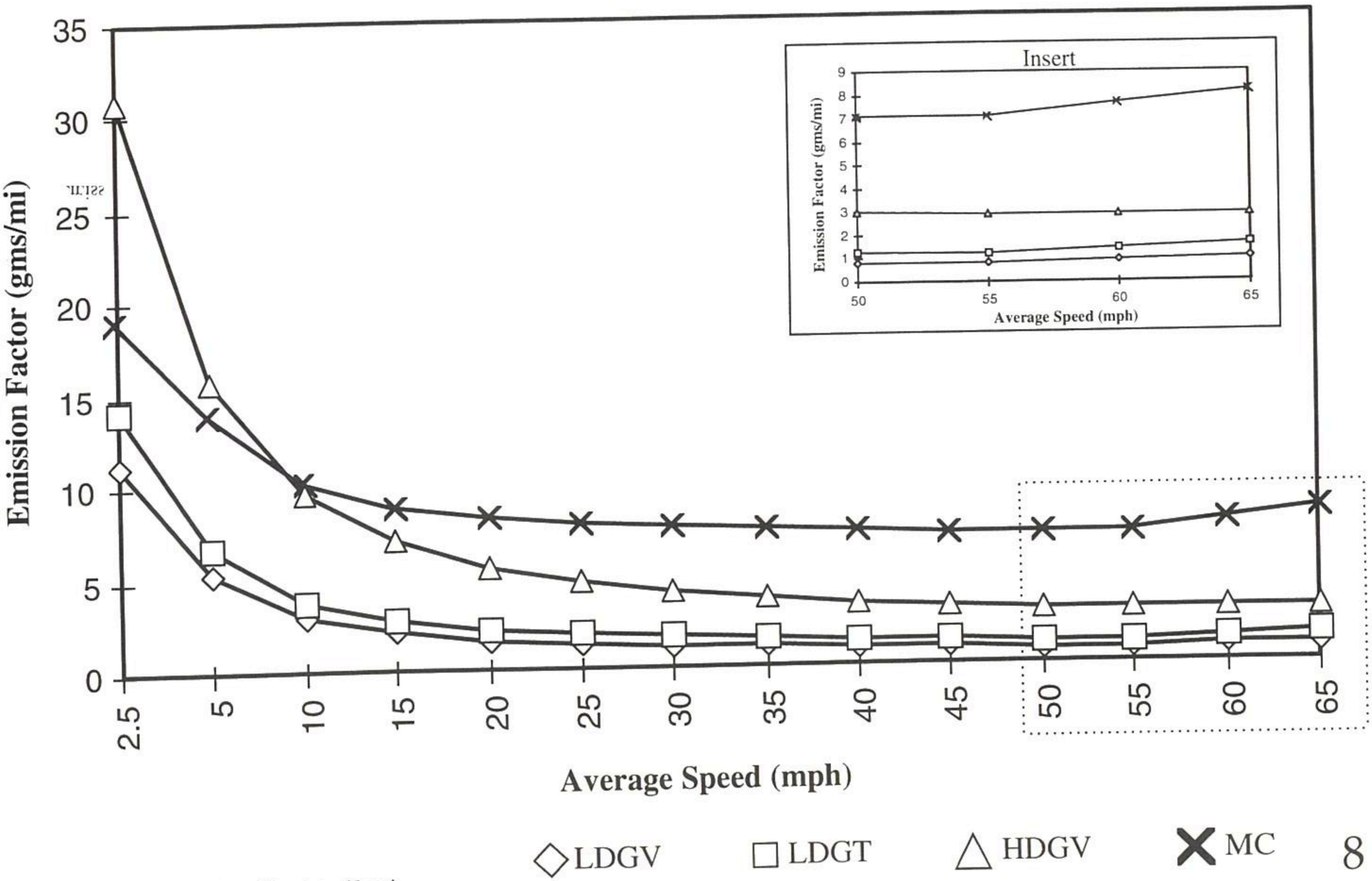
5-County Area Composite Emission Factors



Insert : Emissions Curve from 50 mph to 65 mph

1996 Philadelphia, PA - VOC Emissions Curve

5-County Area Gasoline Vehicle Emission Factors



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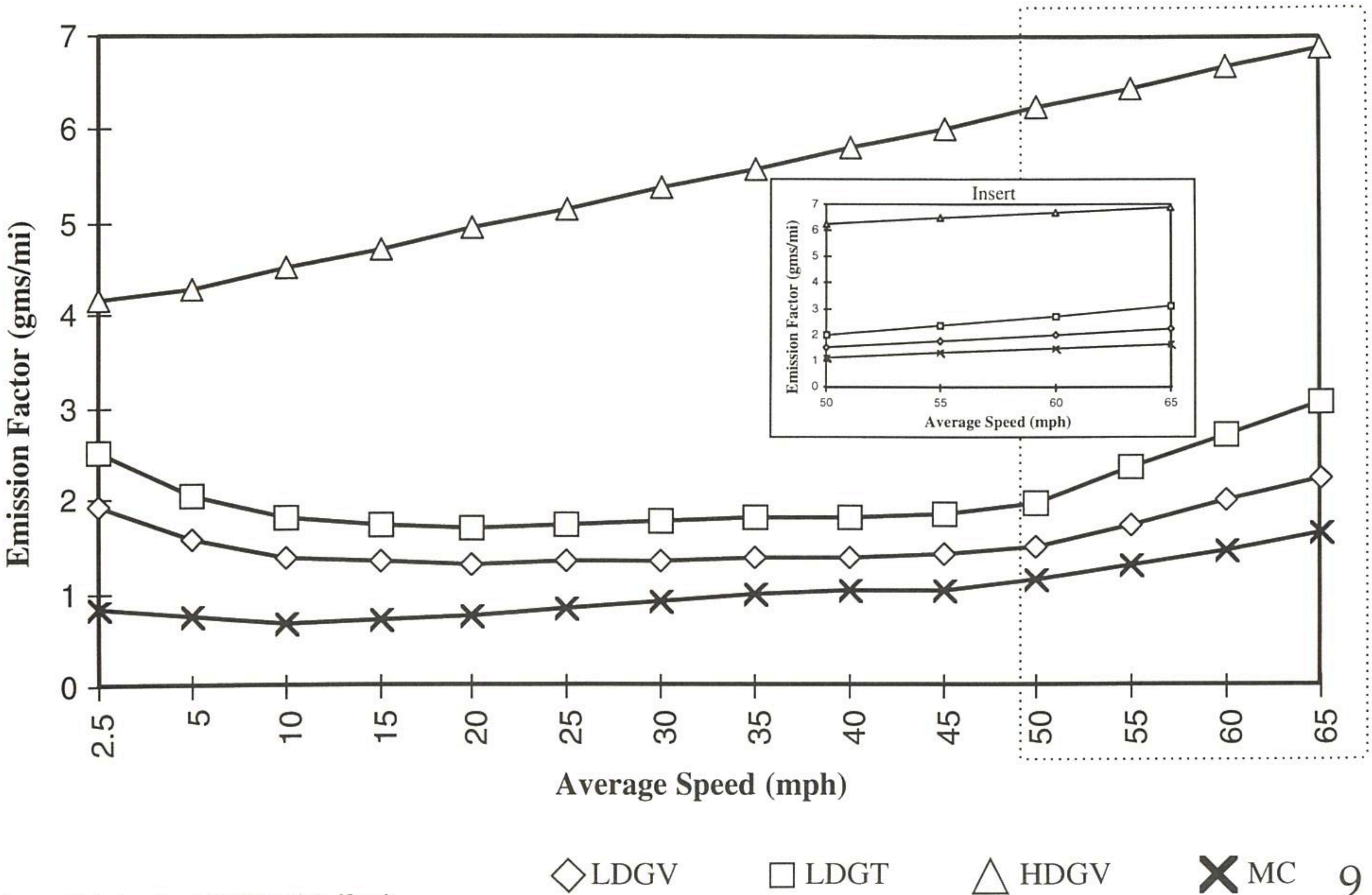
Insert : Er ; Curve from 50 mph to 65 mph

1996 Philadelphia, PA - NOx Emissions Curve

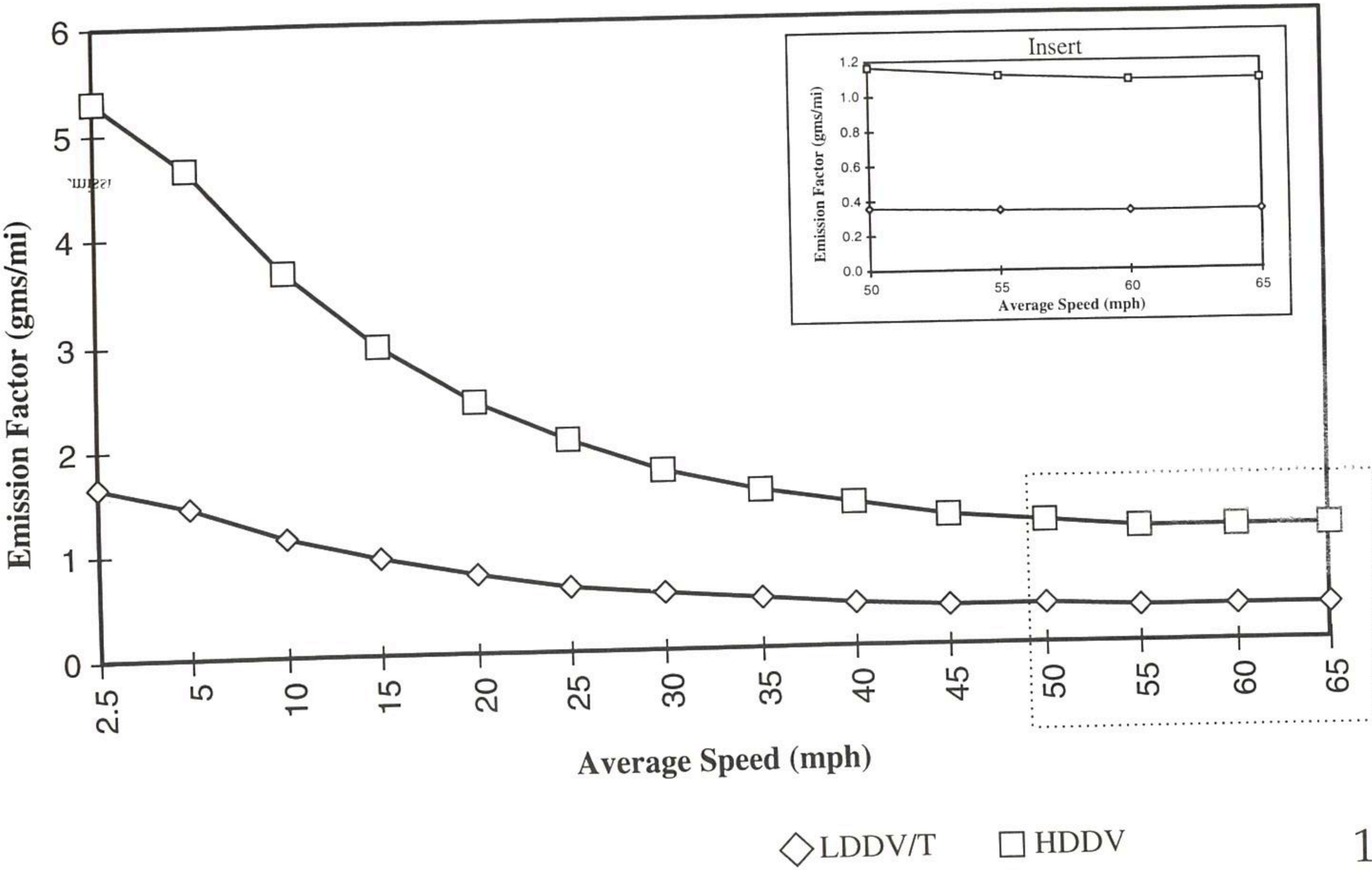
5-County Area Gasoline Vehicle Emission Factors



Insert : Emissions Curve from 50 mph to 65 mph

1996 Philadelphia, PA - VOC Emissions Curve

5-County Area Diesel Vehicle Emission Factors



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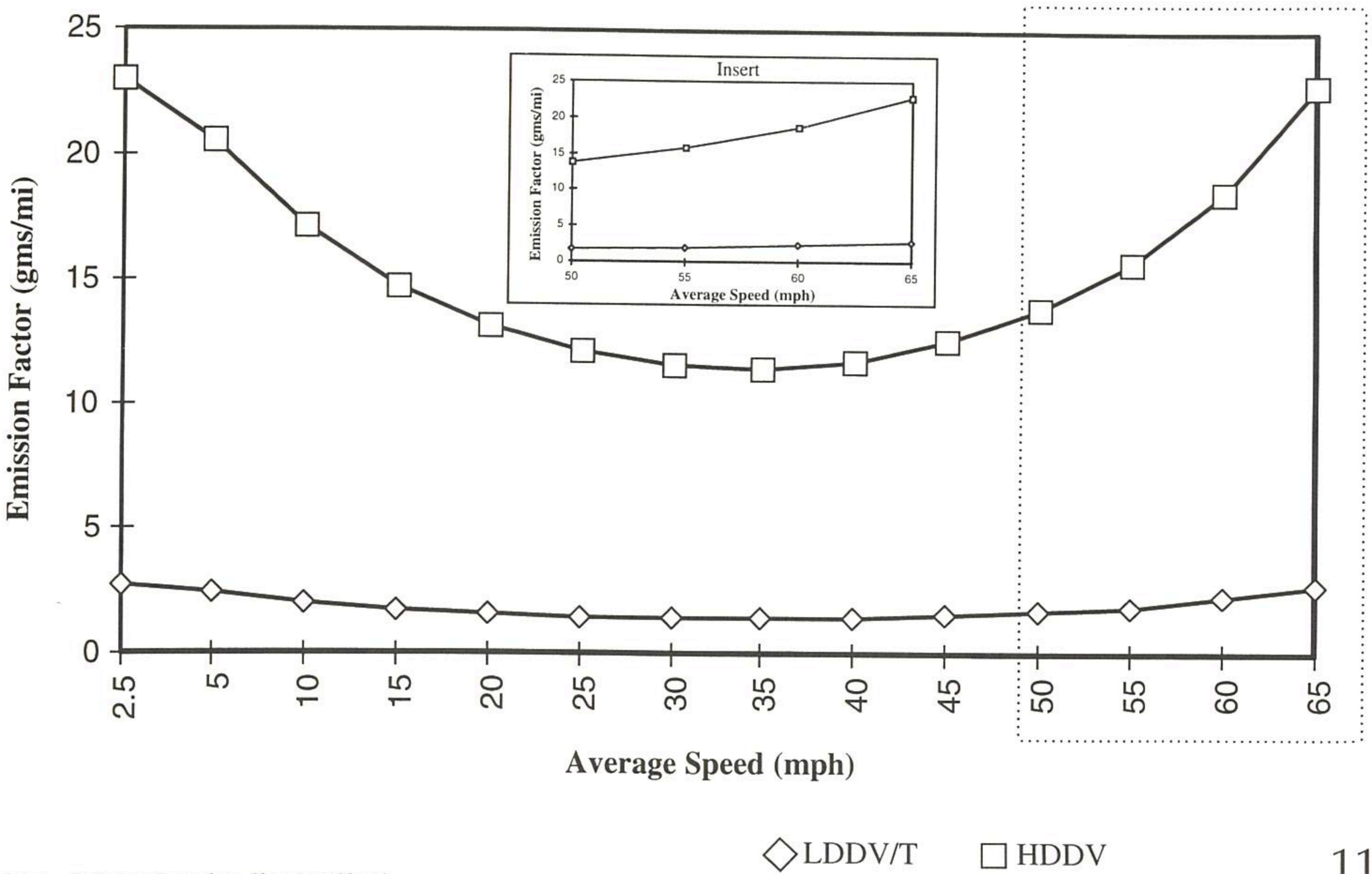
1996 Philadelphia, PA - NOx Emissions Curve

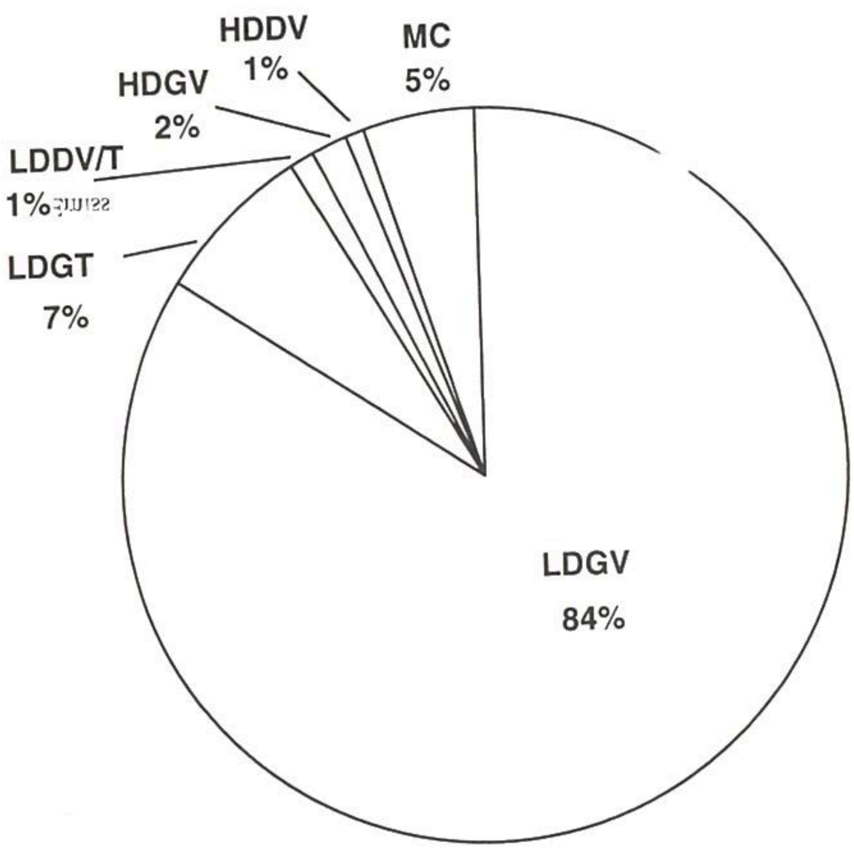
5-County Area Diesel Vehicle Emission Factors

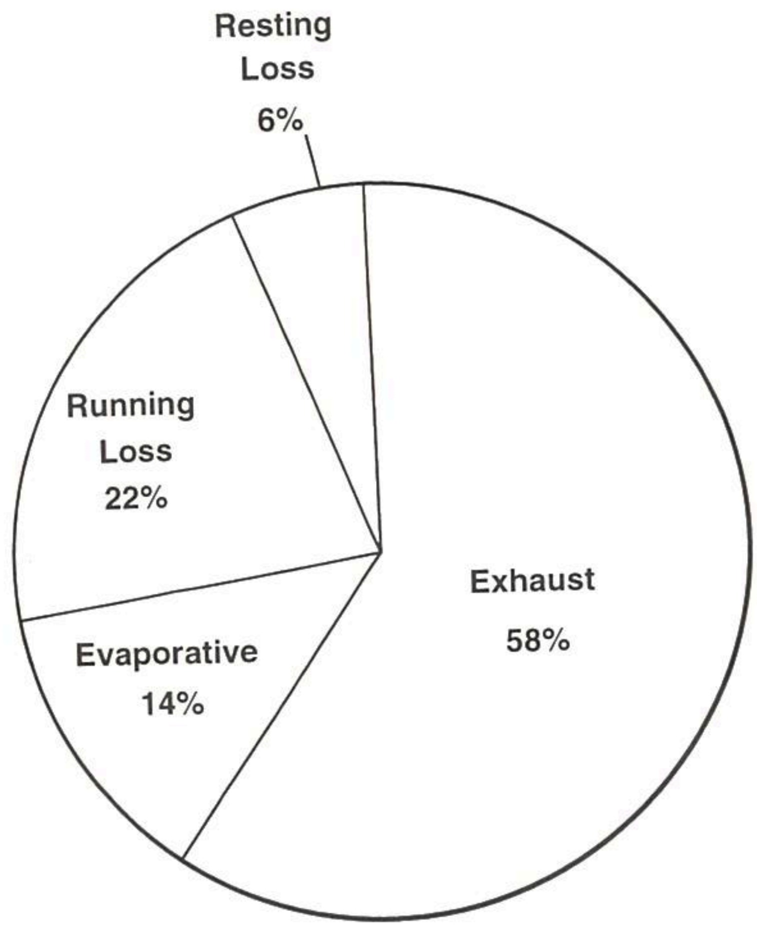


Insert : Emissions Curve from 50 mph to 65 mph

1996 Philadelphia, PA - VOC Emissions by Components

5-County Area Total On-Highway VOC Emissions





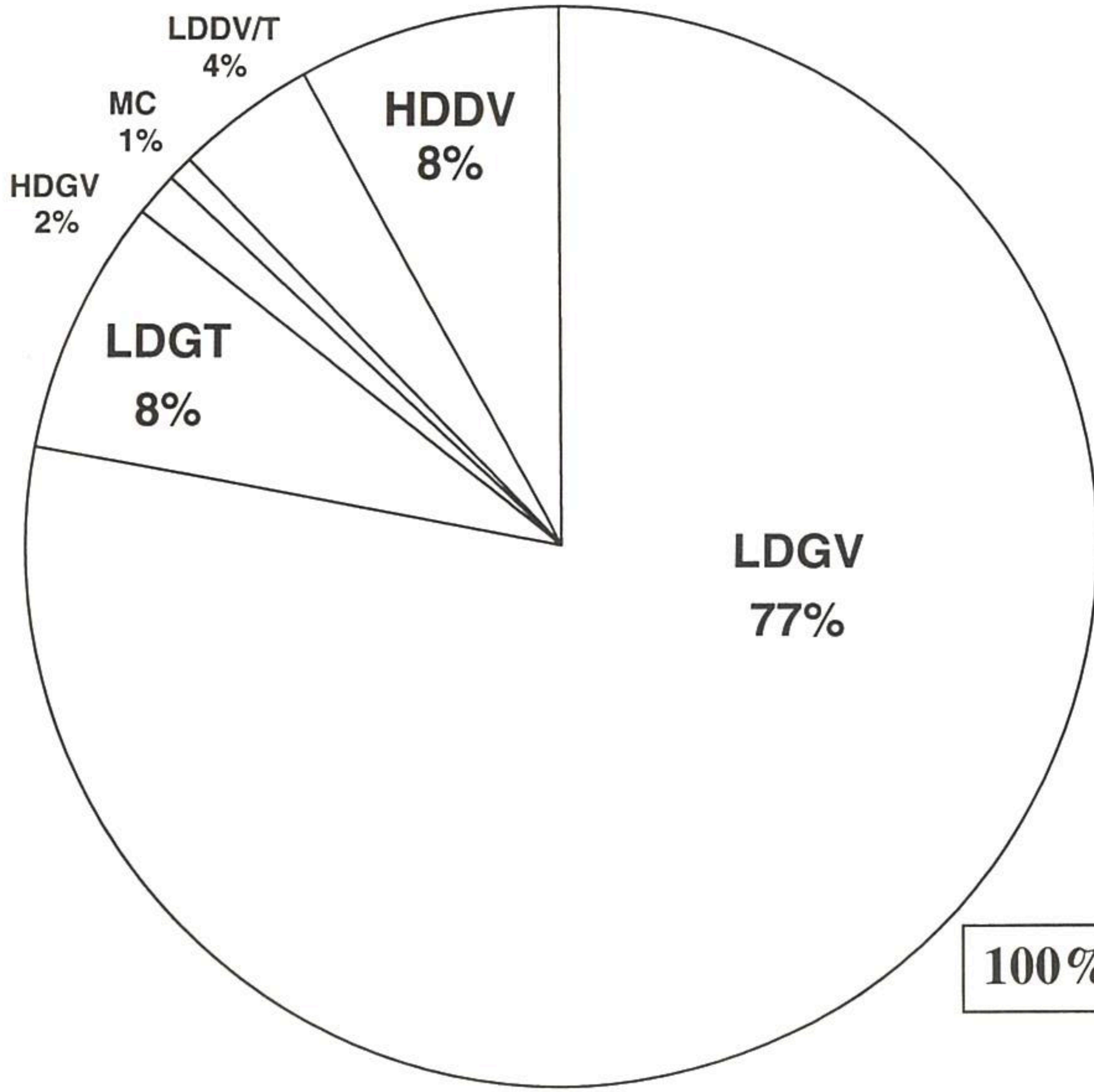
Exhaust:	Emissions from the tail pipe of an operating vehicle
Evaporative:	Evaporative emissions occurring while the vehicle is stationery and ambient temperatures are rising
Resting Loss:	Evaporative emissions occurring while the vehicle is parked and ambient temperatures are the same or decreasing.
Running Loss:	Evaporative emissions occurring while the vehicle is running.

Scenarios: EPA High Enhanced I/M Performance Standard

* Refueling Emissions are accounted for in Area Sources

1996 Philadelphia, PA - NOx Emissions by Components

5-County Area Total On-Highway NOx Emissions

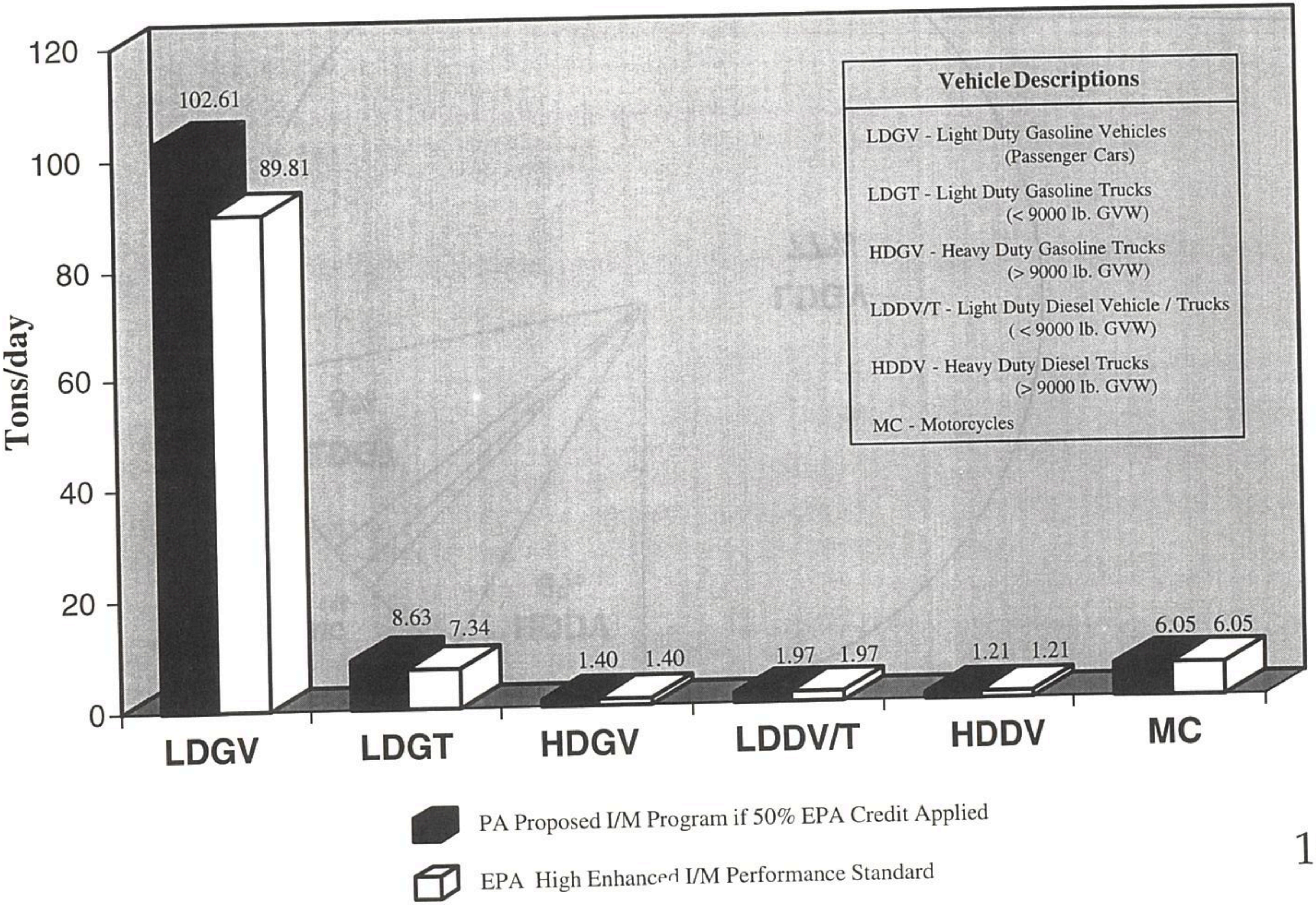


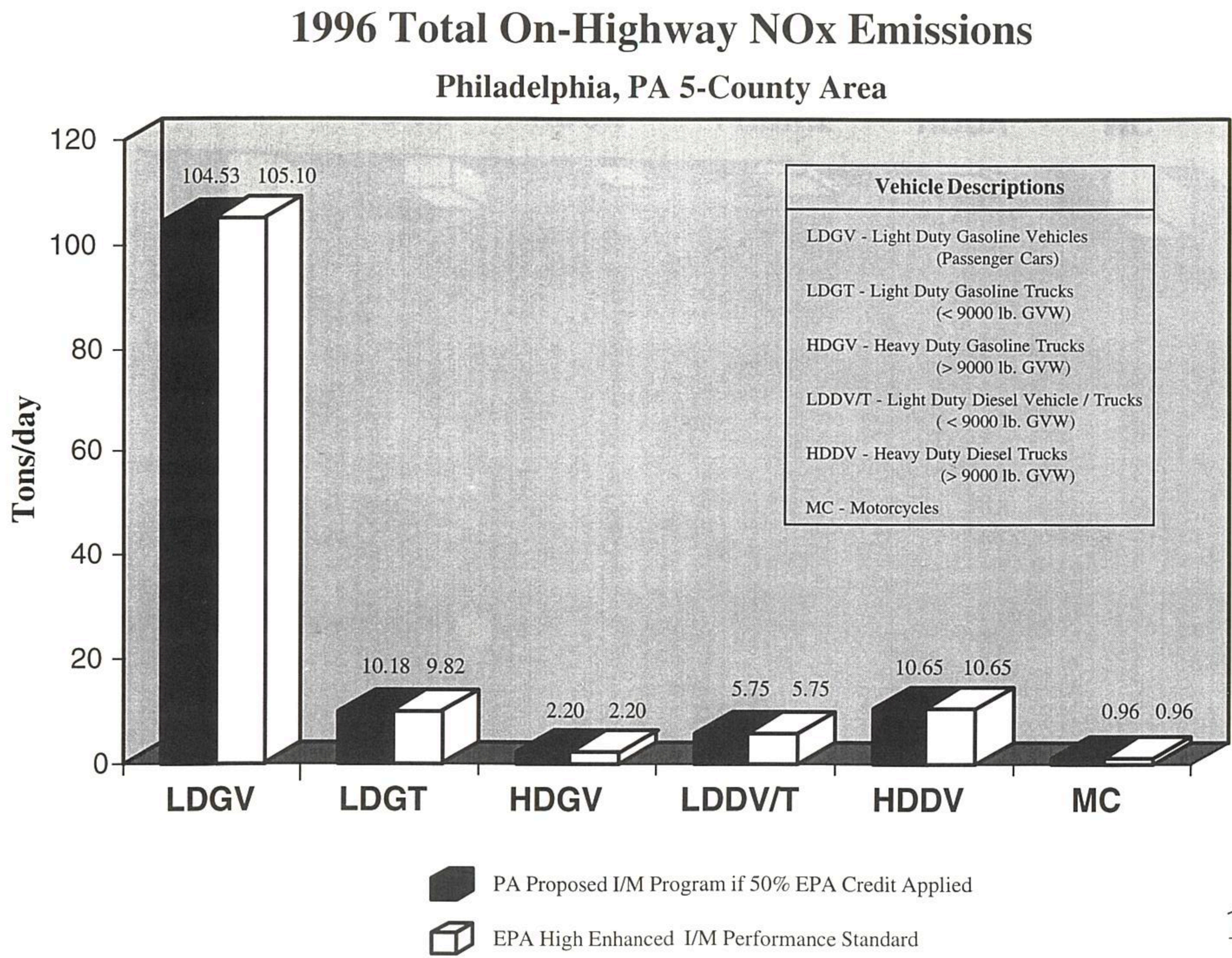
100% from Exhaust

Scenario with EPA High Enhanced I/M Performance Standard

1996 Total On-Highway VOC Emissions

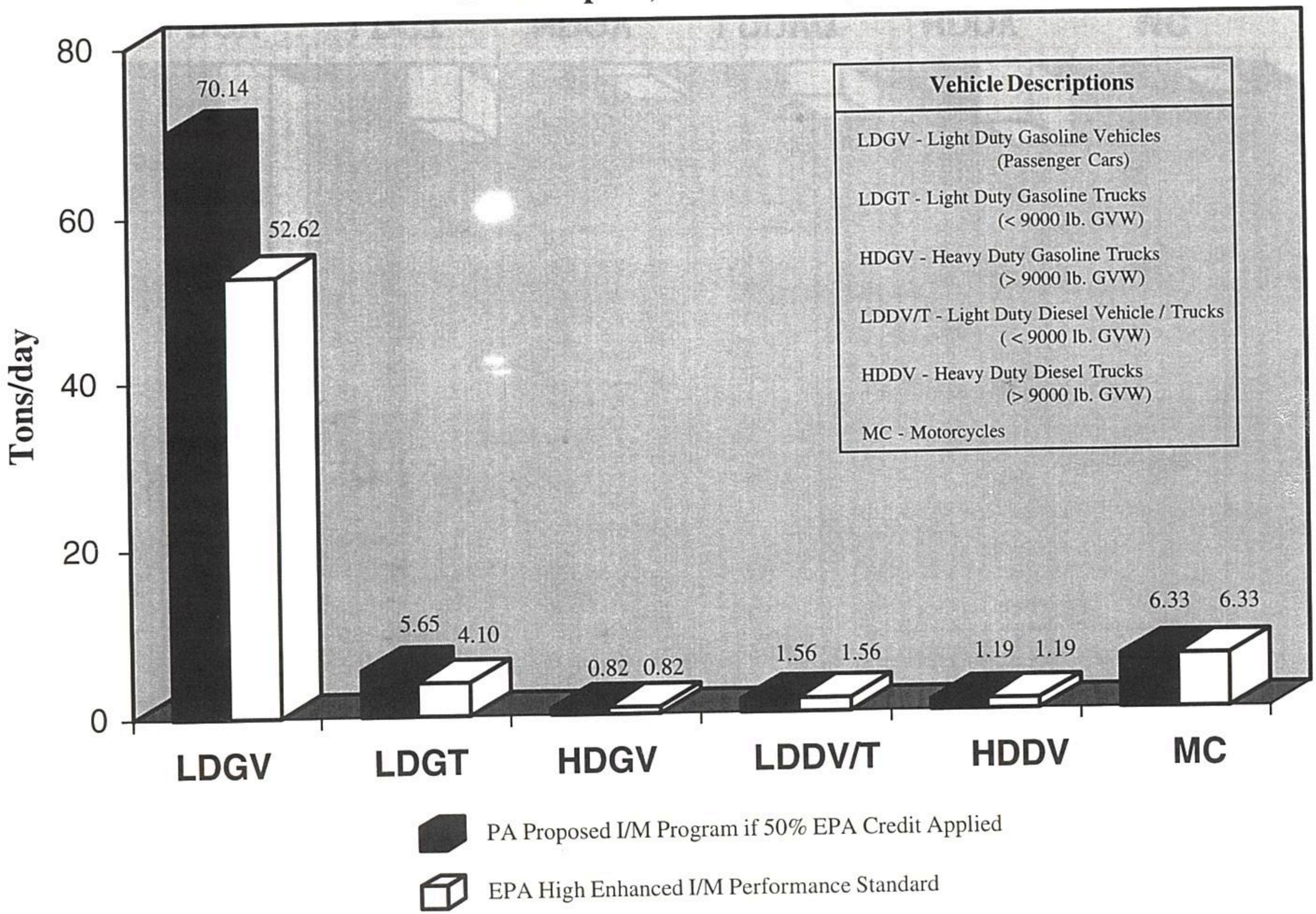
Philadelphia, PA 5-County Area




1996 Total On-Highway NOx Emissions
Philadelphia, PA 5-County Area
Tons/day
120
100
80
60
40
20
0
104.53 105.10
10.18 9.82
2.20 2.20
5.75 5.75
10.65 10.65
0.96 0.96
Vehicle Descriptions
LDGV - Light Duty Gasoline Vehicles (Passenger Cars)
LDGT - Light Duty Gasoline Trucks (< 9000 lb. GVW)
HDGV - Heavy Duty Gasoline Trucks (> 9000 lb. GVW)
LDDV/T - Light Duty Diesel Vehicle / Trucks (< 9000 lb. GVW)
HDDV - Heavy Duty Diesel Trucks (> 9000 lb. GVW)
MC - Motorcycles
LDGV
LDGT
HDGV
LDDV/T
HDDV
MC
PA Proposed I/M Program if 50% EPA Credit Applied
EPA High Enhanced I/M Performance Standard

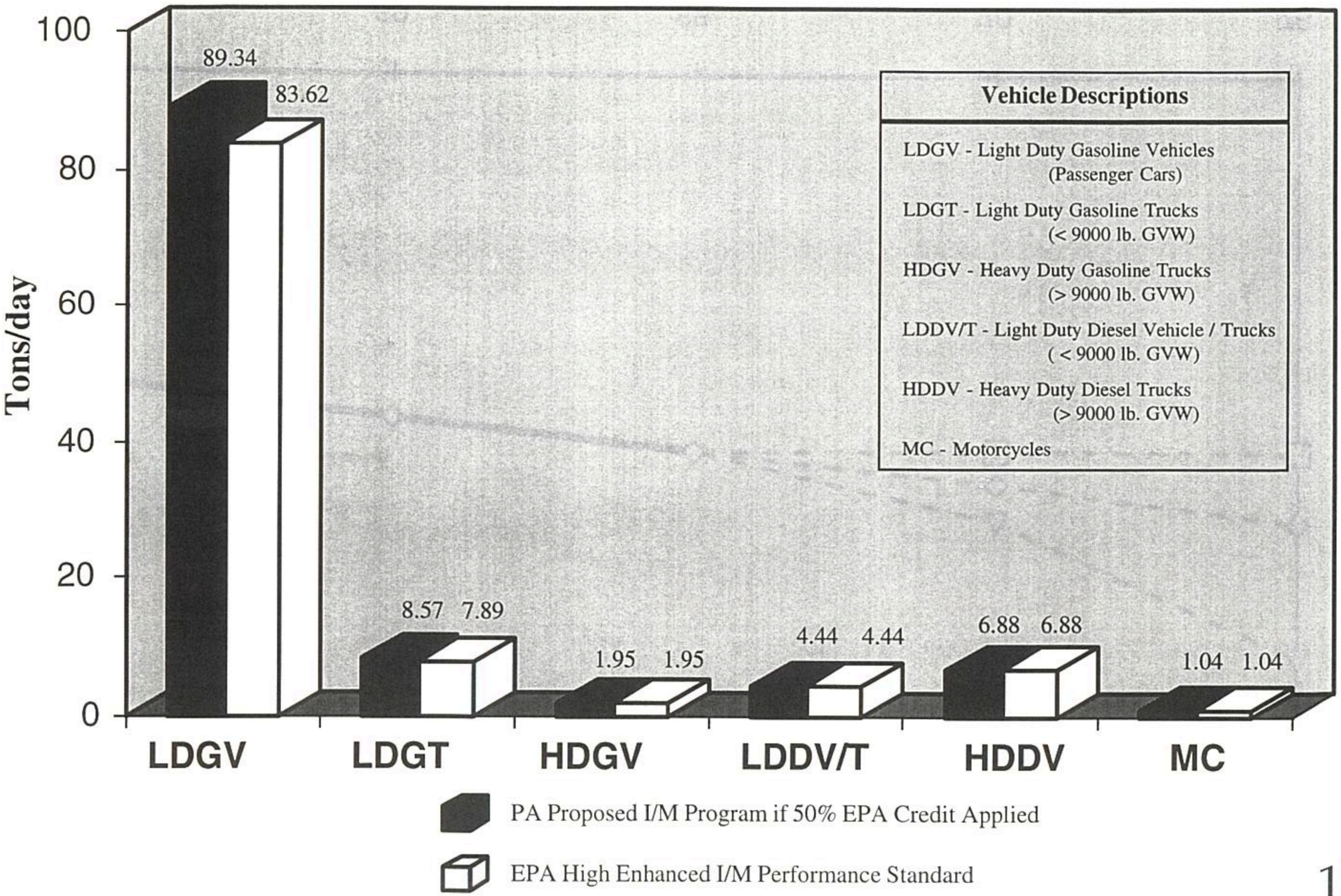
2005 Total On-Highway VOC Emissions

Philadelphia, PA 5-County Area



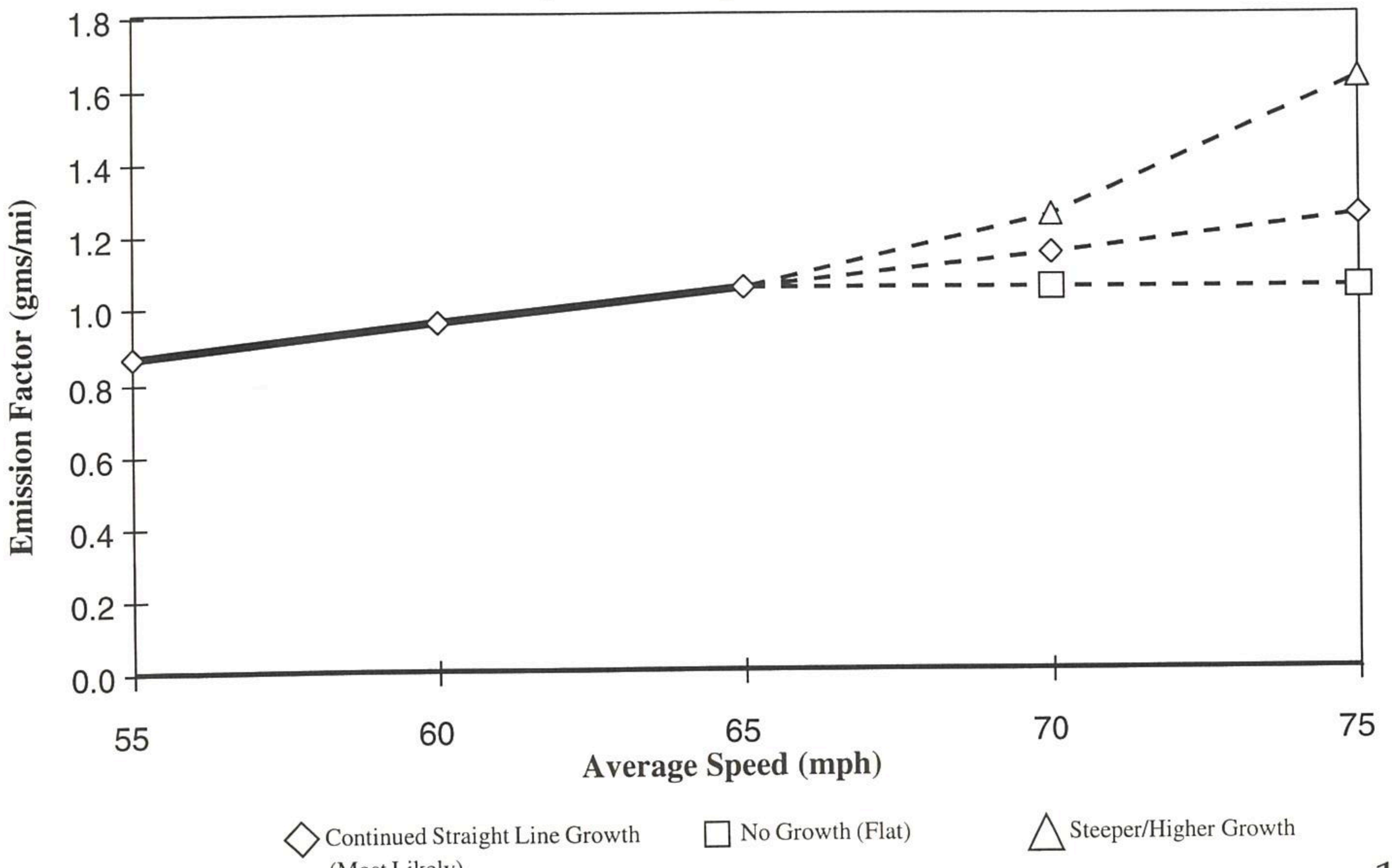
2005 Total On-Highway NOx Emissions

Philadelphia, PA 5-County Area



1996 Philadelphia PA - Conceptual VOC Emissions Curve Scenarios Beyond 65 mph

5-County Area Composite Emission Factors



Scenario wi' High Enhanced I/M Performance Standard

1996 Philadelphia PA - Conceptual VOC Emissions Curve Scenarios Beyond 65 mph

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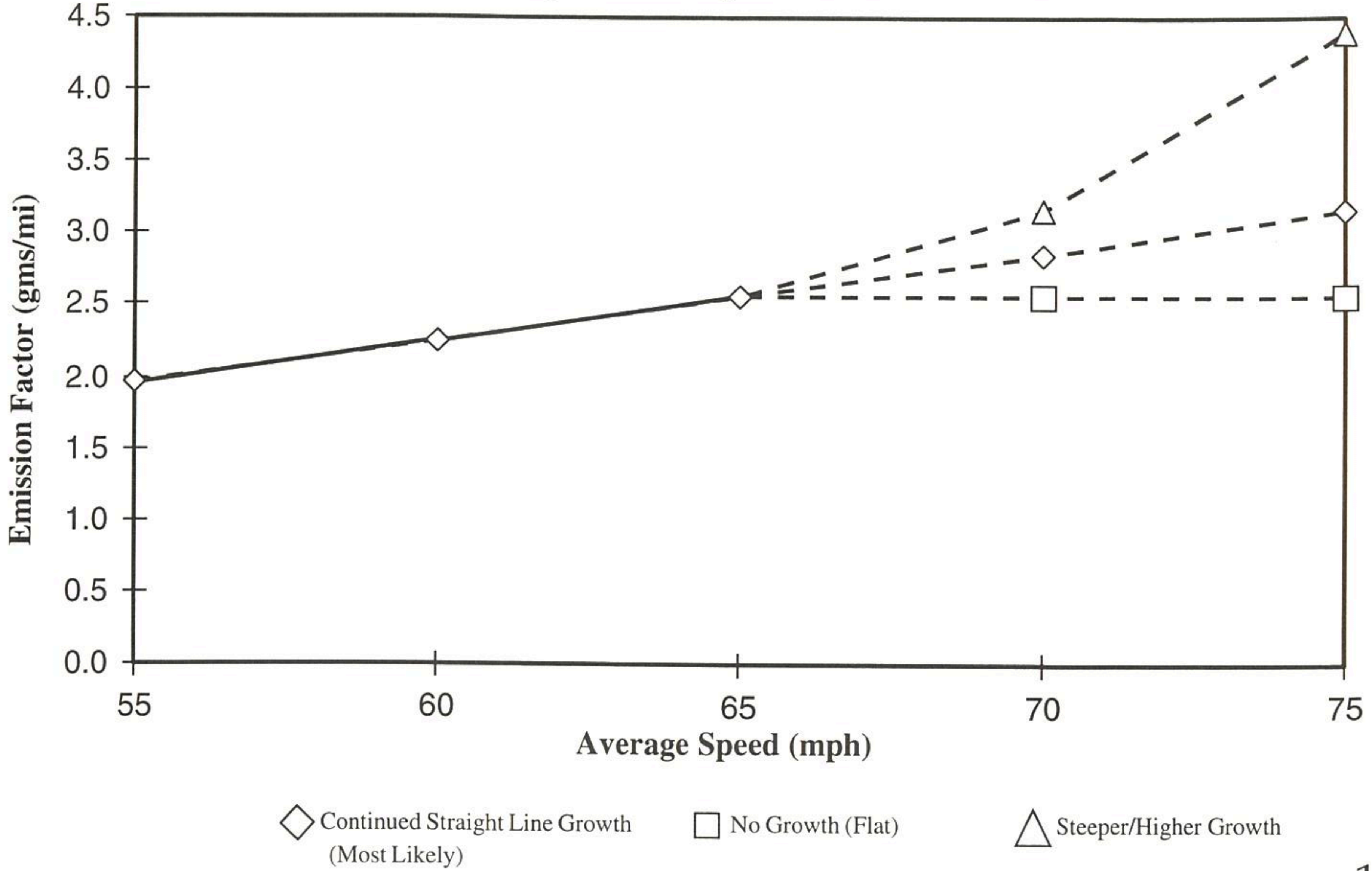


Scenario with EPA High Enhanced I/M Performance Standard

LDGV Emissions vs Speed Changes

- VOC emissions curve slopes downward until 50 to 55 mph where it gradually increases.

- NOx emissions are higher at very slow speeds under 15 mph and over 45 mph with a steeper curve at higher speeds.

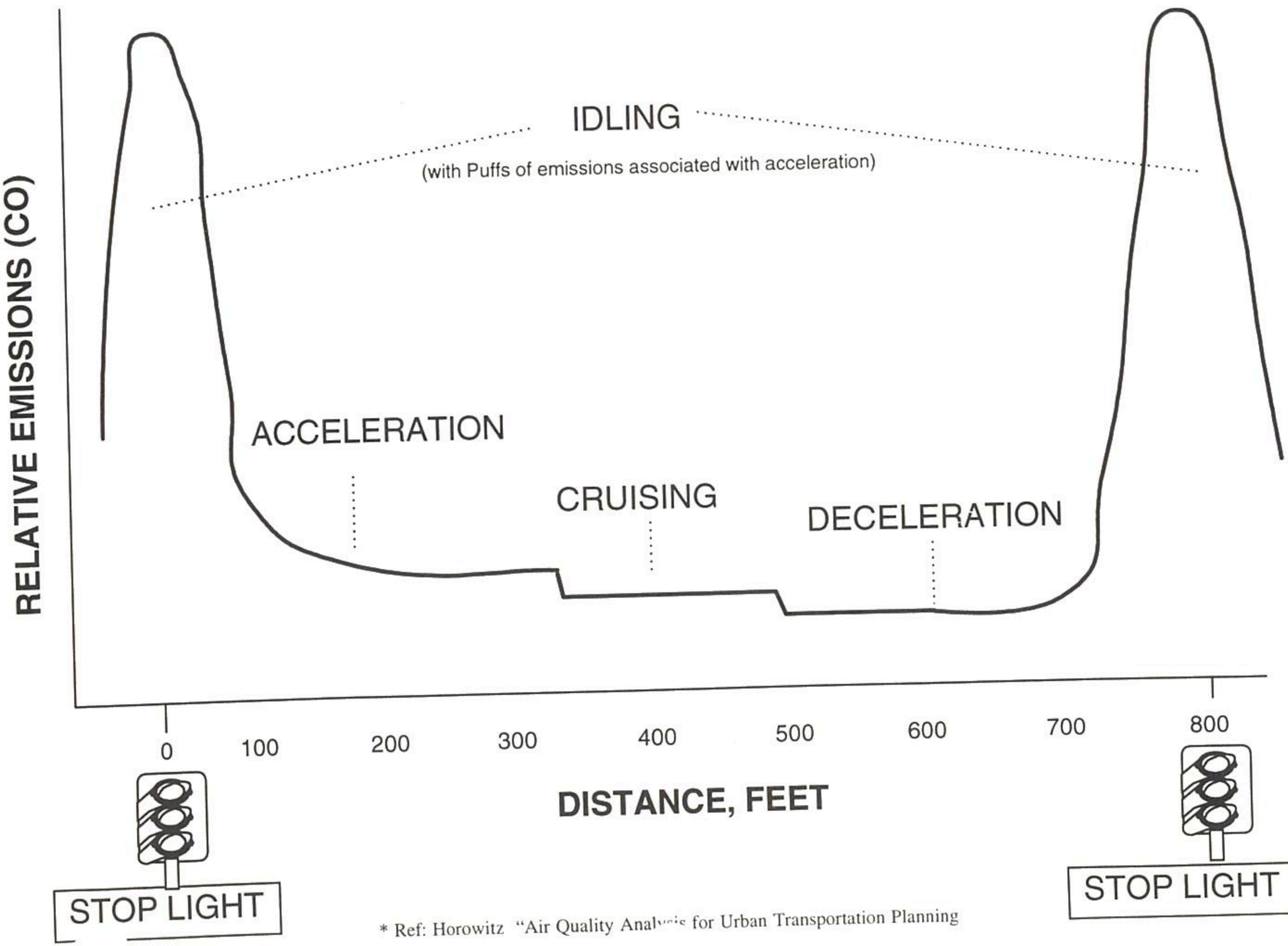
- No definite data or Federal direction to date for speeds greater than 65 mph.

- LDGVs produce 84% of VOCs and 77% of NOx of the total on-highway emissions.

Question 1.b

How do emissions change as a vehicle goes from idling to traveling?

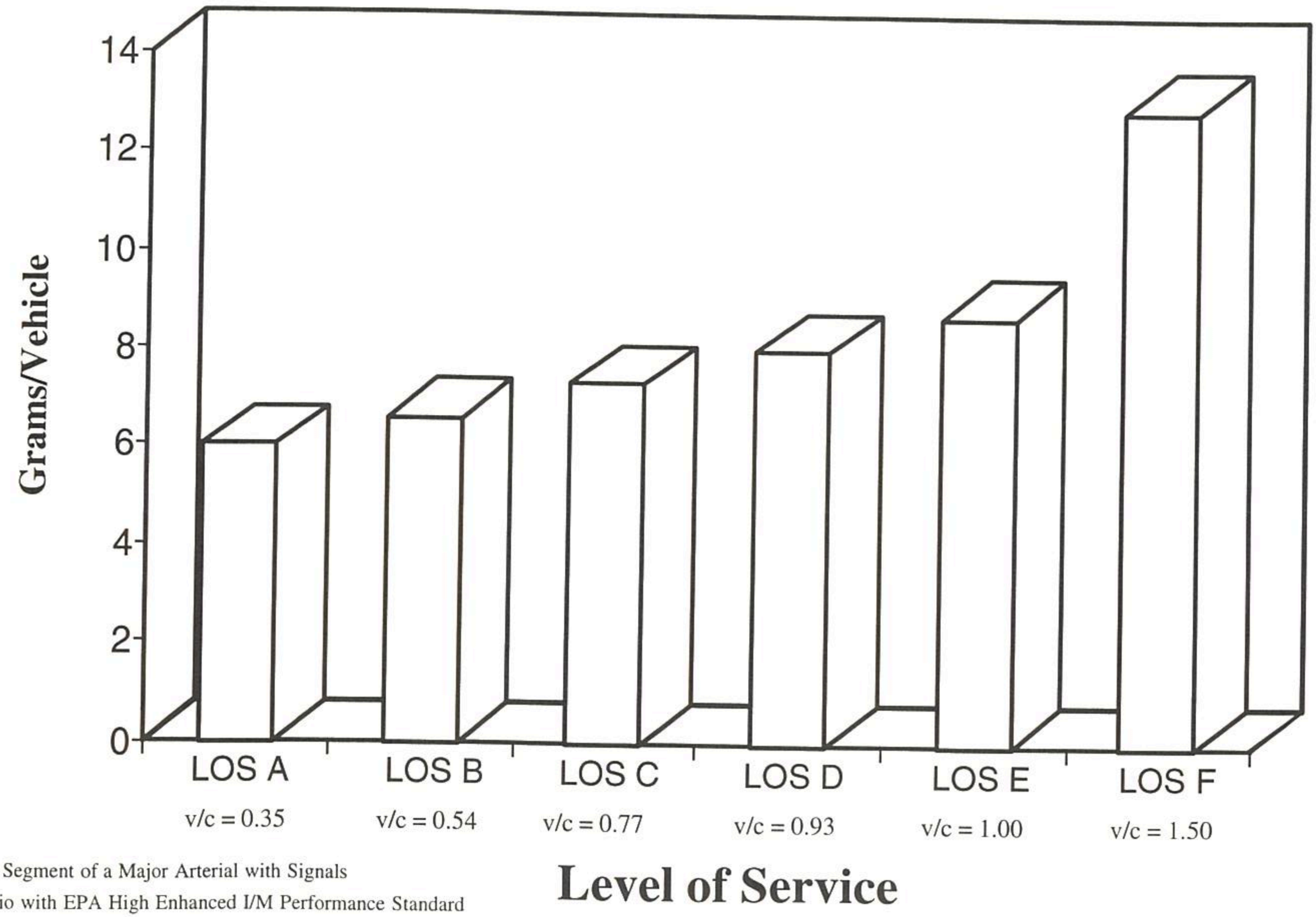
Emissions Pattern Between Two Stop Lights



* Ref: Horowitz "Air Quality Anal[illegible] for Urban Transportation Planning

Average 1996 VOC Emissions for Arterials by LOS

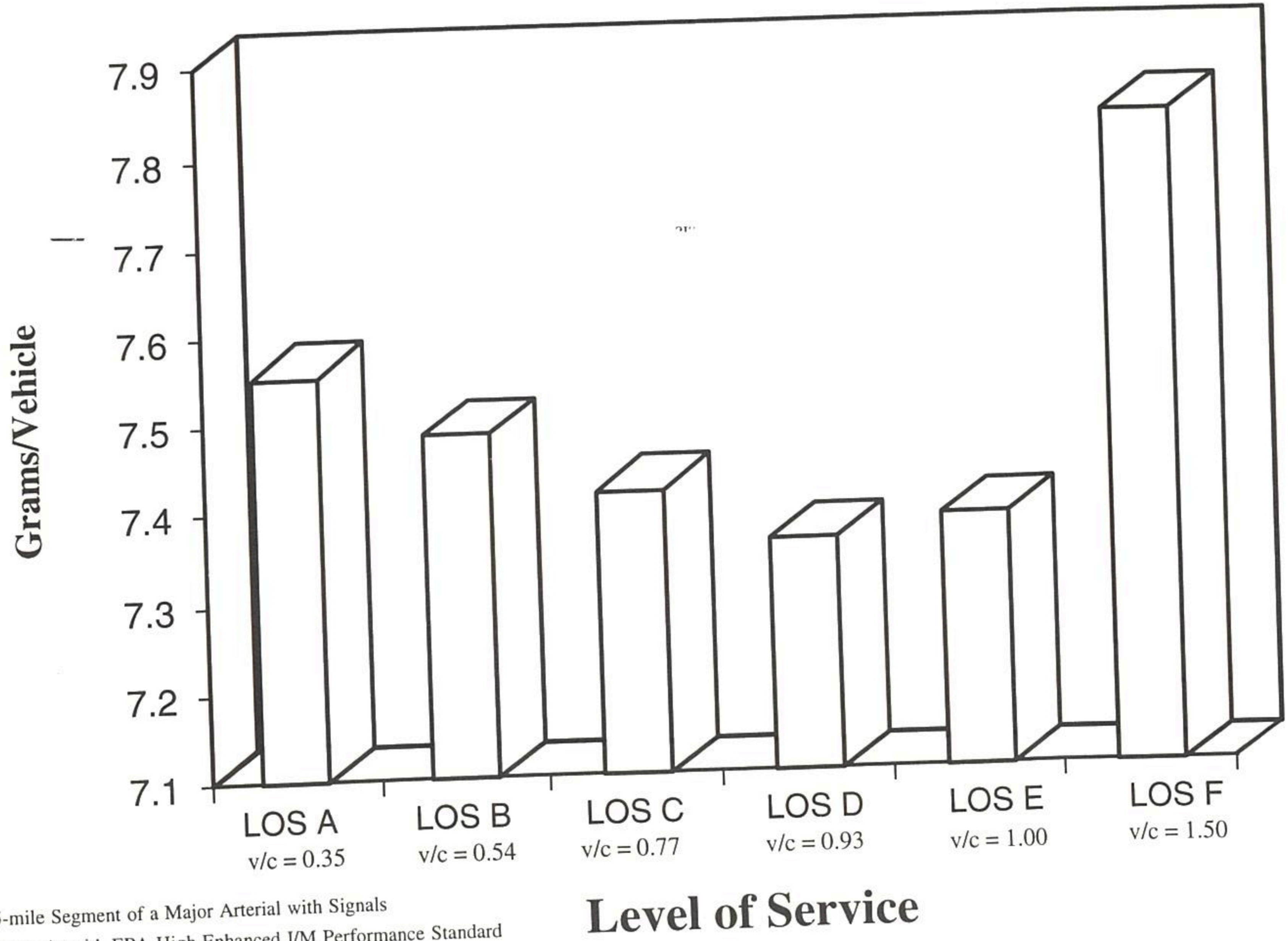
5-County Area On-Highway VOC Emissions



5-mile Segment of a Major Arterial with Signals
Scenario with EPA High Enhanced I/M Performance Standard

Average 1996 NOx Emissions for Arterials by LOS

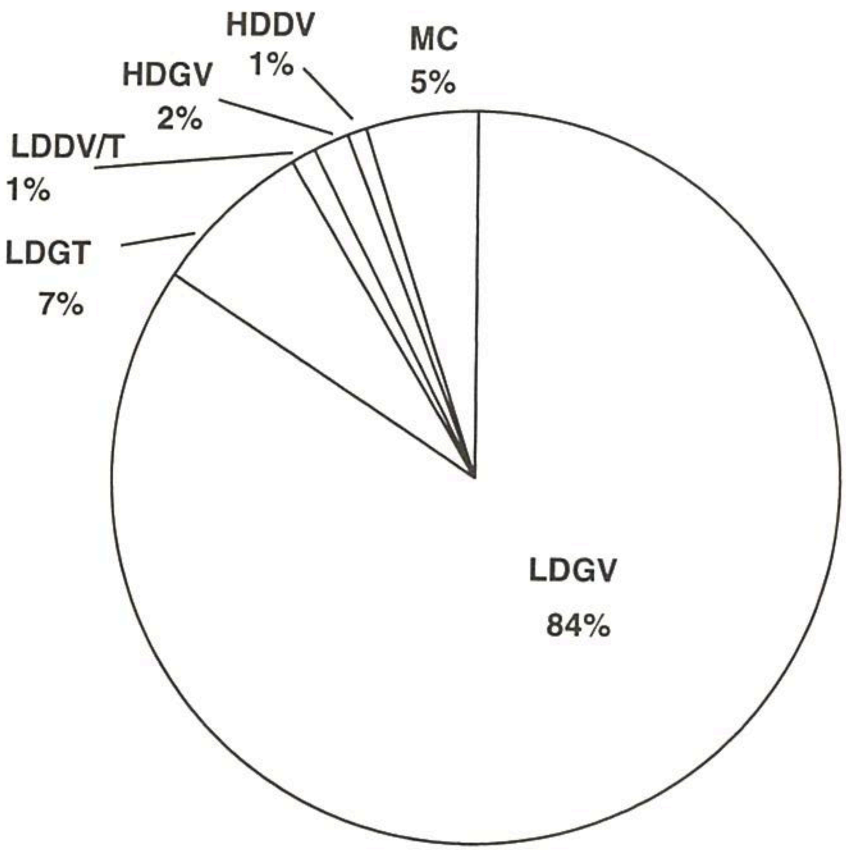
5-County Area On-Highway NOx Emissions

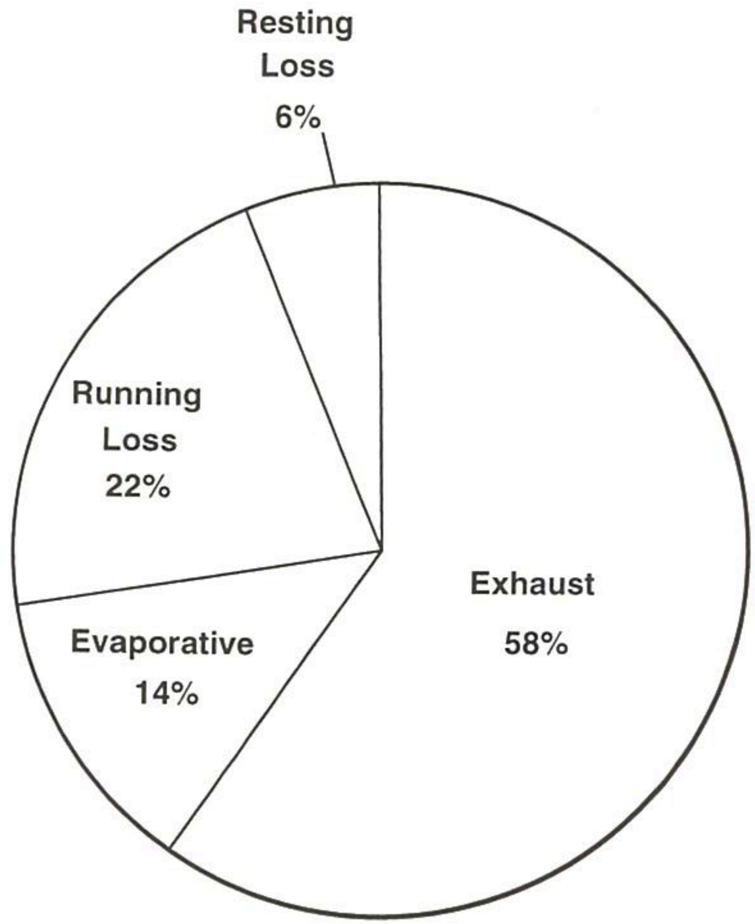


5-mile Segment of a Major Arterial with Signals
Scenario wi·· EPA High Enhanced I/M Performance Standard

1996 Philadelphia, PA - VOC Emissions by Components

5-County Area Total On-Highway VOC Emissions





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Resting Loss:	Evaporative emissions occurring while the vehicle is parked and ambient temperatures are the same or decreasing.
Running Loss:	Evaporative emissions occurring while the vehicle is running.

Scenarios: EPA High Enhanced I/M Performance Standard
* Refueling Emissions are accounted for in Area Sources

Emissions from Typical 20 mile Round Trip

Emissions from:	VOC (grams)	Percentage
Vehicle Starting	10.8	34%
Running	9.8	31%
Idle	5.0	16%
Diurnal	5.8	19%
Total	**31.4**	**100%**

1990 LDGV
Source: CARB

Idling vs Traveling

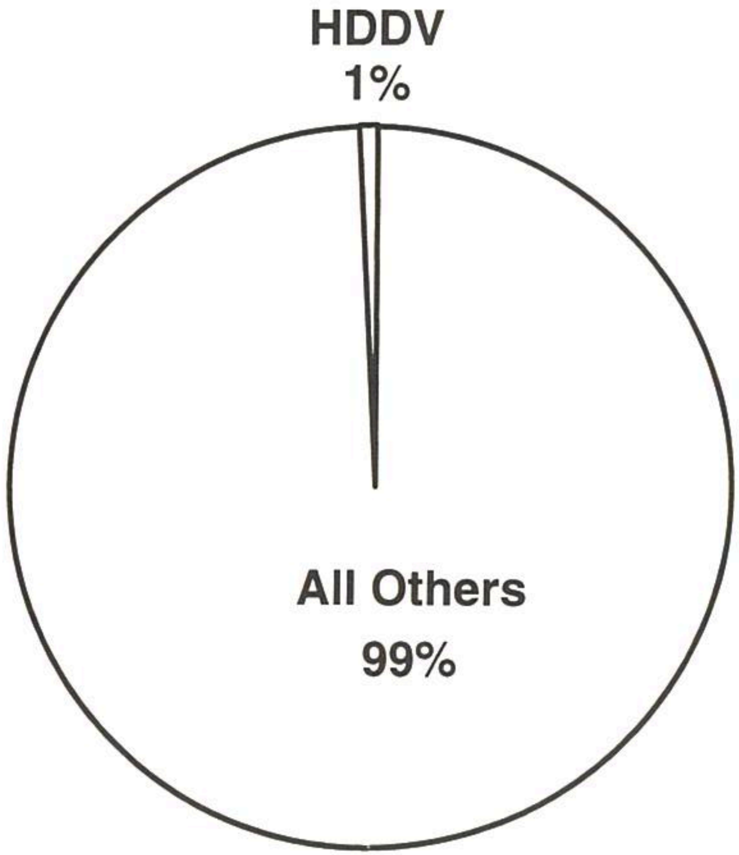
- Highest emissions at extremes of speed range
- Emissions minimized when:
  - Traffic flow is smooth, and
  - Speed of 15 - 30 mph is achieved for NOx
  - Speed of 45 - 55 mph is achieved for VOC
- Approx. 1/3 of emissions in a typical trip occur when the vehicle is started.
- Emissions best minimized by avoiding a vehicle trip.

Question 2

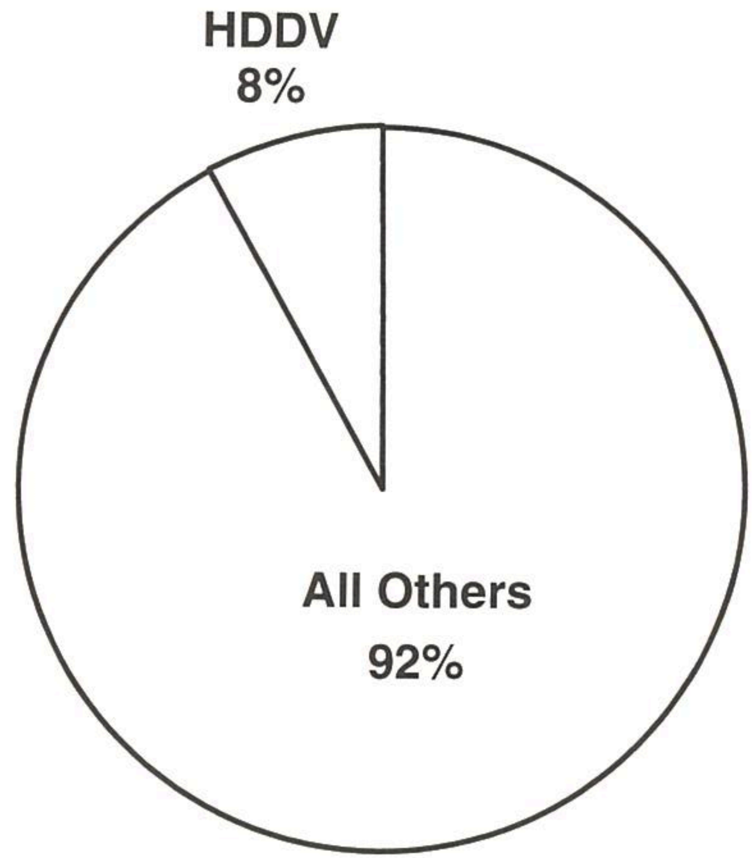
What is the relevance of NOx emissions from heavy-duty trucks?

1996 Heavy Duty Diesel Vehicles VMT and NOx Emissions

Philadelphia, PA 5-County Area Total On-Highway NOx Emissions



VMT

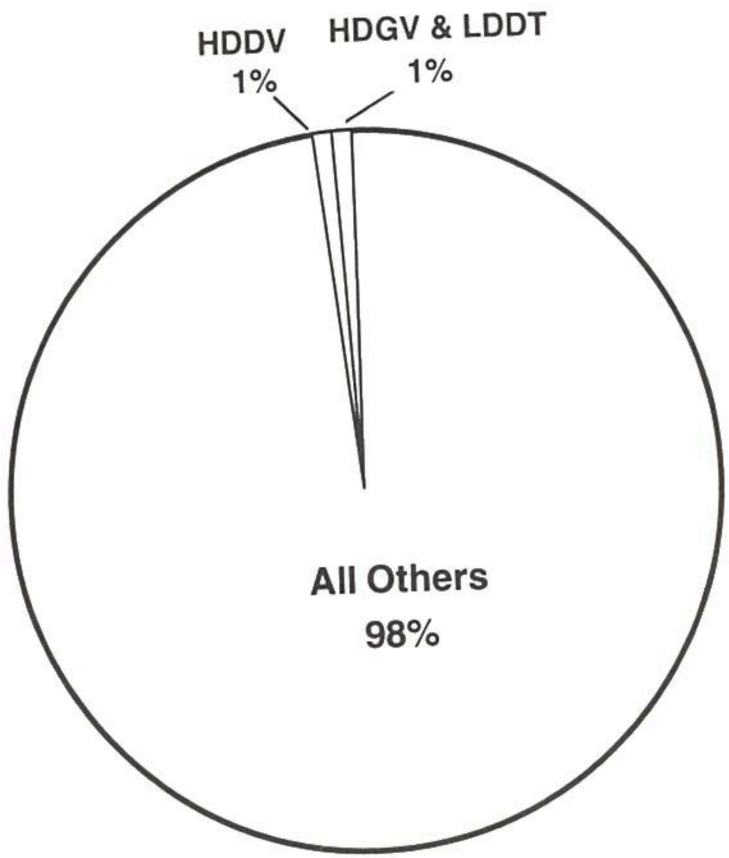


NOx Emissions

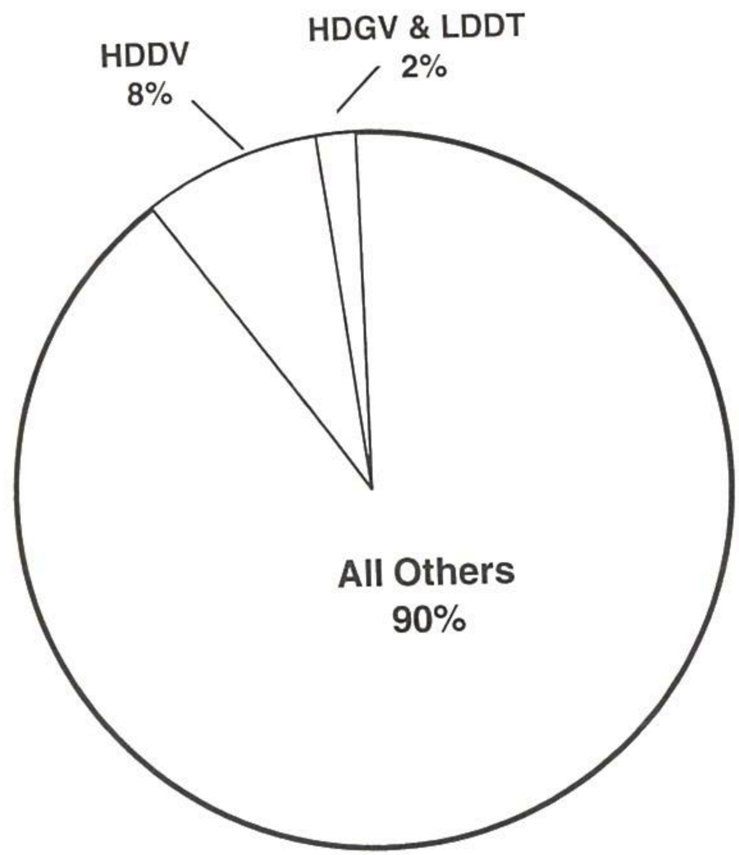
Scenario with EPA High Enhanced I/M Performance Standard

1996 Heavy Duty Trucks VMT and NOx Emissions

Philadelphia, PA 5-County Area Total On-Highway NOx Emissions



VMT

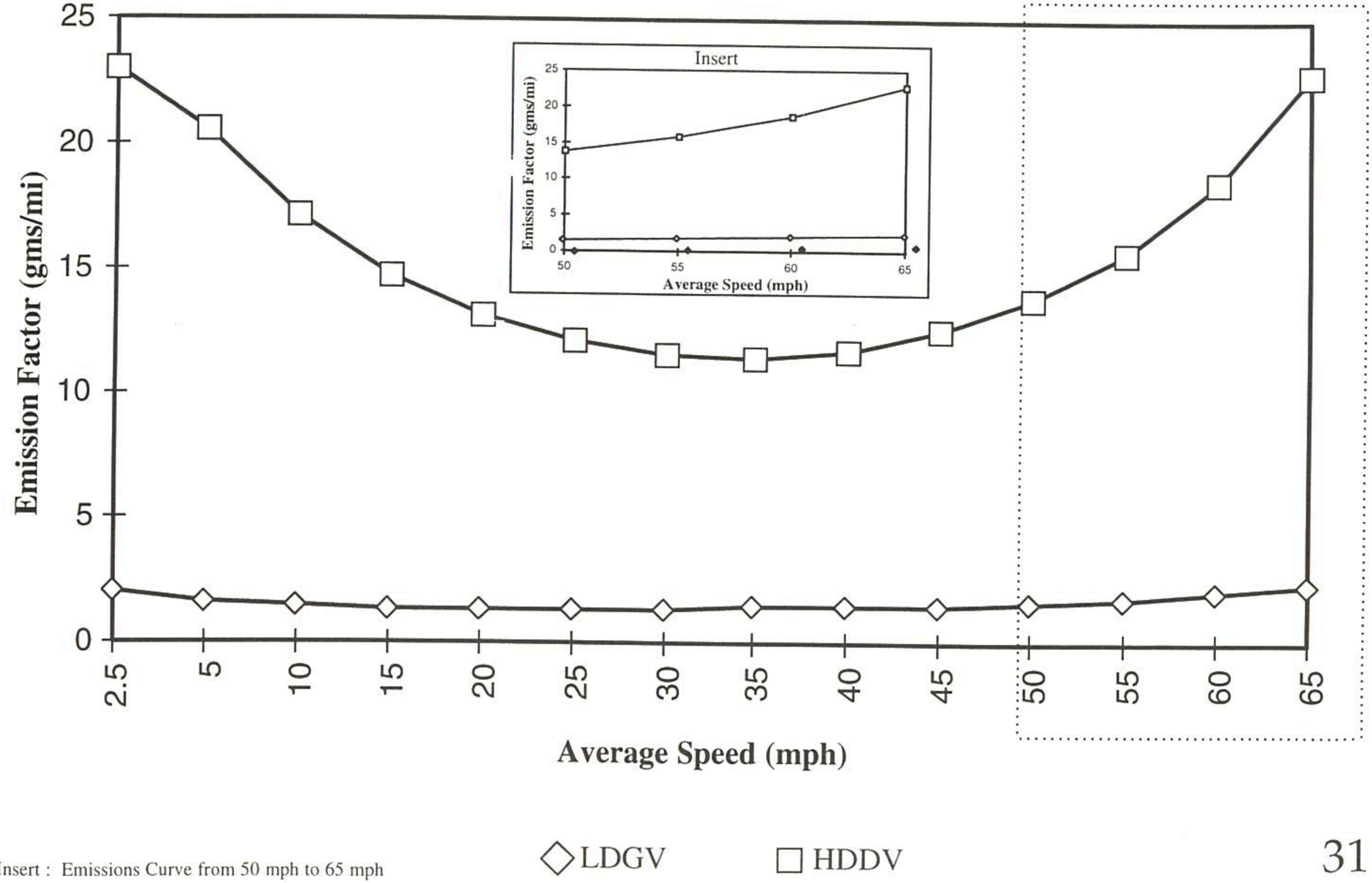


NOx Emissions

Scenario · A High Enhanced I/M Performance Standard

1996 Philadelphia, PA - NOx Emissions Curve

5-County Area Heavy Duty Diesel Vehicle Emission Factors



Insert : Emissions Curve from 50 mph to 65 mph

NOx & Heavy Duty Diesel Trucks (HDDV)

- 6-14 times more NOx per mile from HDDV than LDGV.
- Dramatic NOx emissions increases for speeds > 45 mph.
- Dramatic NOx emissions decreases as speed increases from 0 to 20 mph.
- HDDV comprise 0.12% of fleet, 1% of VMT, & 8% of NOx.
- HDGV & LDDT emissions
  - 1.71% of fleet and 2% of NOx emissions.

Question 3

What is the attainment benefit from traffic signal synchronization?

Questions 3. What is the attainment benefit from traffic signal synchronization?

The attainment benefit is interpreted to mean the benefit in vehicular emissions from traffic signal synchronization. The various studies utilized unique methodologies, but the emissions benefit results are of similar magnitude.

Figure 3.1 Traffic signal synchronization projects analyzed by PennDOT in 1994 for CMAQ funding.

The analyses performed by PennDOT utilized sketch planning techniques and emissions spreadsheets to calculated travel and emissions impacts.

Factors that impact the emissions benefits of the proposed improvement:

Traffic volume
Average speed of the corridor
Speed limit
Level of service (LOS)
Area/facility type
Additional roadway and intersection improvements
Traffic diversions

Findings: Signal synchronization increases average speed which decreases VOC and may marginally increase or decrease NOx depending upon project improvement.

Figure 3.2 Transportation Control Measures for DVRPC.

The TCM analysis performed by DVRPC utilized sketch planning techniques to create link update records reflecting the signalization improvements. These record updates were used to modify trip tables from DVRPC's network based transportation model for traffic re-assignment. PPAQ was then used to determine the emissions impacts of the proposed improvement. The improved flow conditions produced higher average speeds which resulted in lower vehicle emission rates. VMT impacts were assumed from traffic diversions due to the improved traffic flow conditions.

Figure 3.3 Transportation Control Measures for Connecticut

The TCM analysis performed by ConnDOT utilized spreadsheet and database-oriented sketch planning tools to estimate the speed improvement on the state's most congested arterials.

Figure 3.1 Traffic Signal Synchronization Progjects
Philadelphia 5-County Area

County	Project Name	Improvement	Travel / Emissions Impacts*		
			Ave Speed (mph)	VOC (kg)	NOx (kg)
Bucks	State Rd; State Rd - US 1	Corridor Improvements, interconnect 11 signals, w/ minor widening	+0.98	-9.5	-0.2
Bucks	Newton Twp; Closed Loop System	Install computerized signal system @ 19 intersections	+0.86	-3.4	+0.3
Chester	PA 41 @ State St and 1st Ave	Upgrade and interconnect 2 signals	+1.46	-0.5	0.0
Chester	West Chester Borough	Install computerized signal system @ 24 intersections, w/ minor widening	+0.69	-5.1	-0.3
Delaware	PA 3; N. Lawrence - 69th St	Install computerized signal system @ 23 intersections, & lengthen standby lane	+1.14	-17.9	-1.8
Delaware	Edgemont Ave; Upland - Dutton Mill Rd	Interconnect 7 signals, w/ minor widening	+1.31	-4.4	-0.4
Delaware	PA 320; Martins to Woodland	Upgrade traffic signals @ 5 intersections, length standby lane	+1.74	-1.7	0.0
Philadelphia	US 1; 9th St - Bucks Co. Line	Signal optimization @ 35 intersections	+0.60	-21.3	+0.2
Philadelphia	Broad St; Spring Garden St. - Mont. Co. Line	Upgrade signals @ 20 intersections	+0.25	-12.2	-1.4
Philadelphia	Frankford Ave; Bridge St - Bucks Co. Line	Interconnect 33 signals	+1.24	-10.0	0.0
Philadelphia	CBD Broad St; South St - Spring Garden St	Install computerized signal system @ 230 intersections	+0.50	-42.0	-5.2
Philadelphia	State Rd; Cottman - Bucks Co. Line	Interconnect 7 signals	+1.10	-1.5	0.1

*Minimal impact on VMT and Vehicle Trips

**Projects Analyzed by PennDOT for 1994 CMAQ Program

Source: Congestion Mitigation and Air Quality (CMAQ) Analysis Process for Pennsylvania, March 1994

Figure 3.2 Traffic Signal Synchronization Projects

DVRPC TCM Evaluation Study

Improvement	Change in Total VMT	Change in Emissions		
	VMT % Change	VOC (kg) % Change	CO (kg) % Change	NOx (kg) % Change
1996 Base Condition 5-County Philadelphia Area	71,701,500	79,500	510,500	111,000
Advanced signals systems on 50 miles of the most congested 4-lane arterials	-70,544 -0.1%	-135 -0.2%	-545 -0.1%	-145 -0.1%
Advanced signal system improvements - Comprehensive system for Philadelphia CBD	-7,336 0.0%	-32 0.0%	-227 0.0%	-25 0.0%

*Travel and emissions impact summary for an average summer weekday
**Change in vehicle trips not calculated

Source: TCMs, an analysis of potential Transportation Control Measures for implementation in the Pennsylvania portion of the DVRPC region, May 1994

Figure 3.3 Traffic Signal Synchronization Projects
ConnDOT TCM Evaluation Study

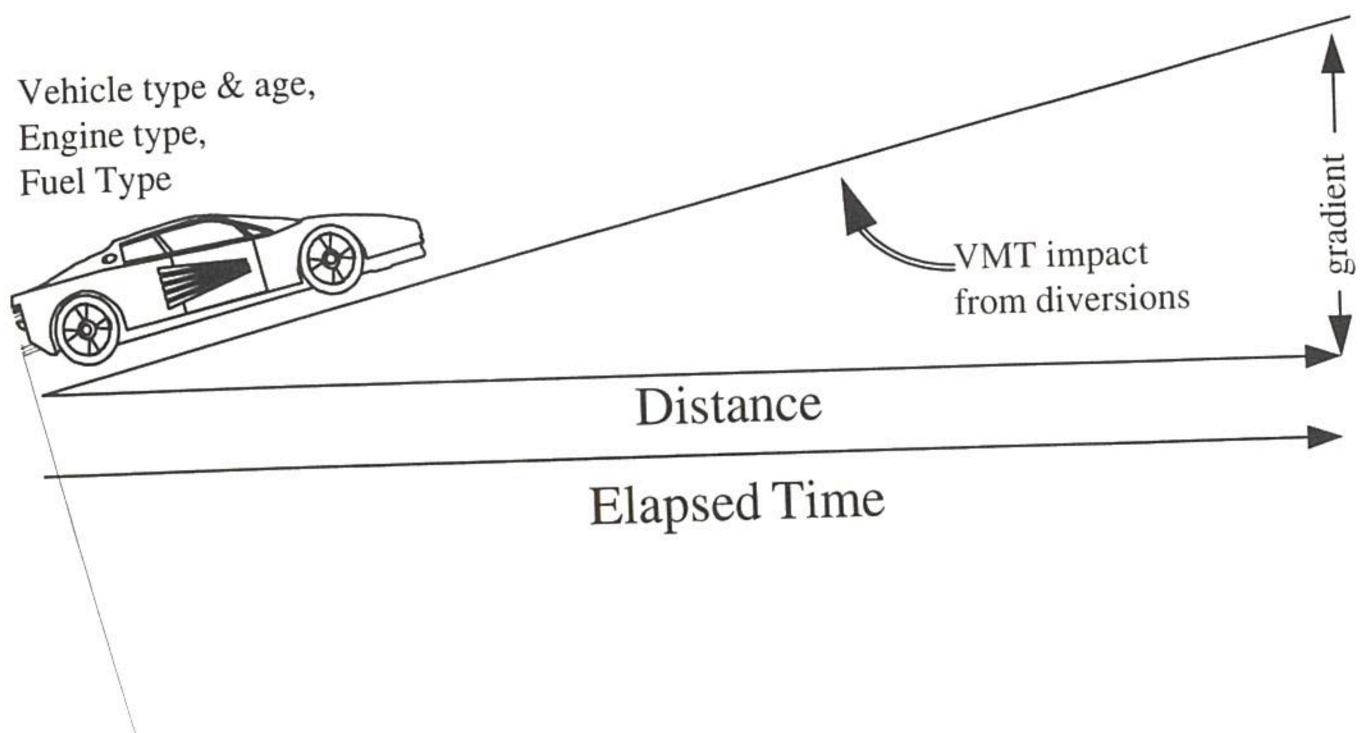
Improvement/Year	Change in Total VMT	Change in Emissions VOC (kg) (tpd)	NOx (kg) (tpd)
ATMS - Computerized coordination of signals on the State's most congested arterials			
1999	No Change	-245 -0.270	-299 -0.330
2007	No Change	-254 -0.280	-318 -0.350

*ATMS - Automated Traffic Management Systems

Source: Connecticut TCM Evaluation Study, Final Report, December 1994

Drive Cycle Impacts on Emissions

Idle	Acceleration	Cruise	Deceleration	Idle



Emissions & Traffic Signal Synchronization

- Evidence to date shows small emissions decreases.
- Largest impact derived from application to most congested arterials -- raises speed and follows decreasing emissions curve from 0-25 mph.
- Need sufficient impact on average speed over a sufficient distance.
- Analytical tasks currently incomplete:
  - MOBILE uses <u>average</u> speed only.
  - Drive cycle research now ongoing.

Question 4

What is the attainment benefit from land-use controls?

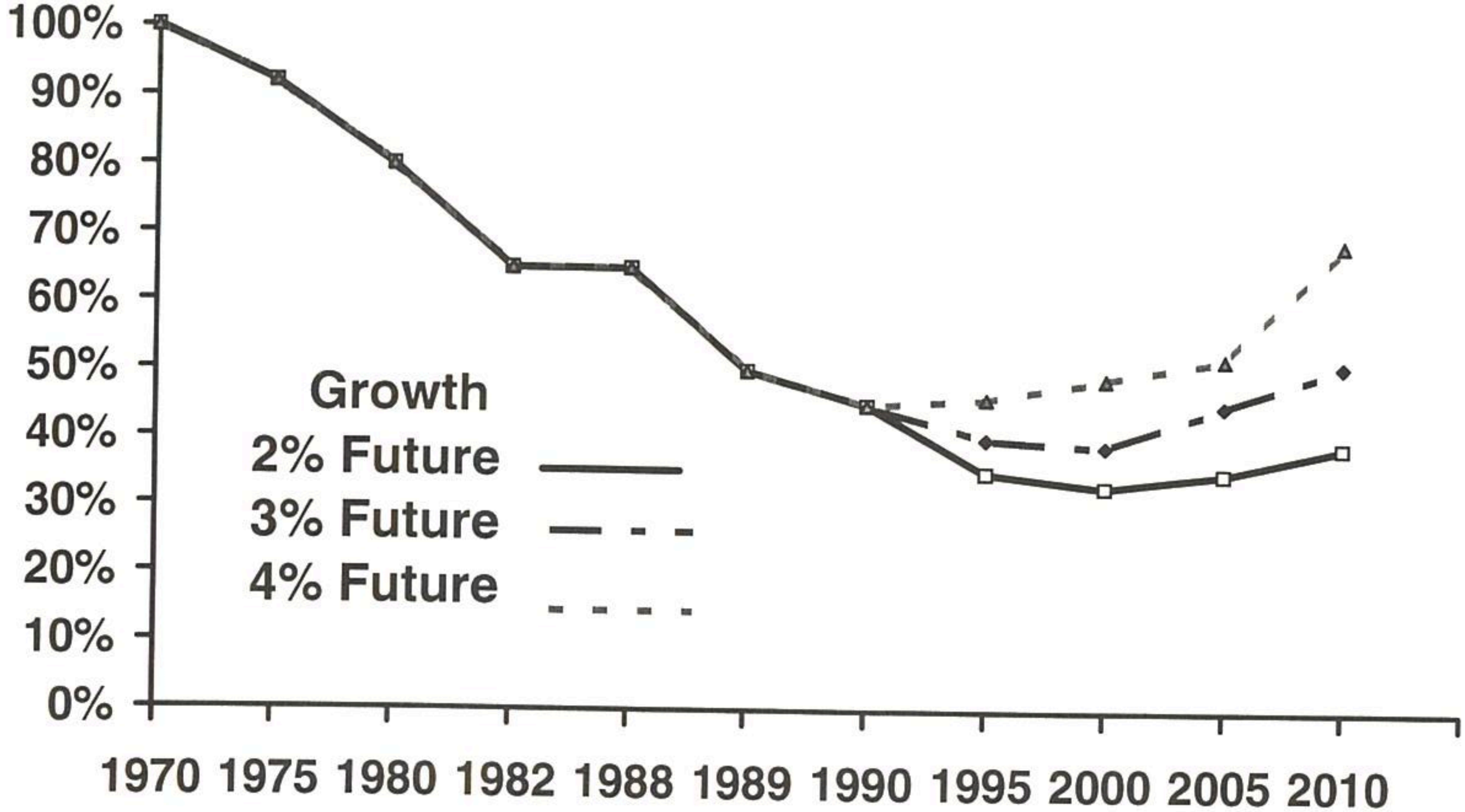
Land-Use Strategies to Improve Air Quality

- Overview of Relationship between Land Use and Air Quality
- Evidence of the Effectiveness of Land-use Strategies
- Conclusions

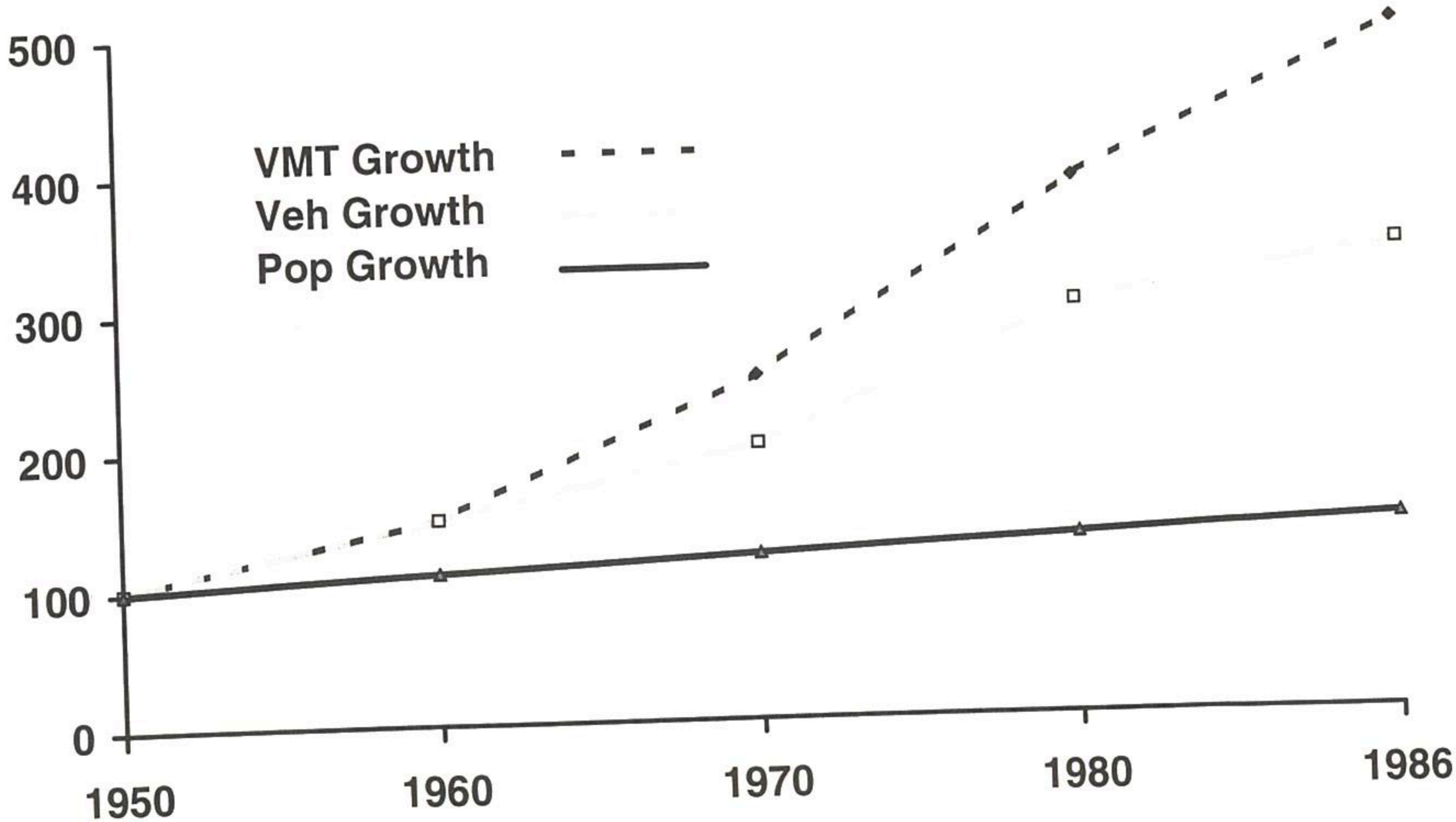
Nature of the Air Quality Problem

- Ozone - Regional, Summer Problem
- VOC and NOx are Key Pollutants of Interest
- CO and PM10 "Hot Spots" Not Currently Problem

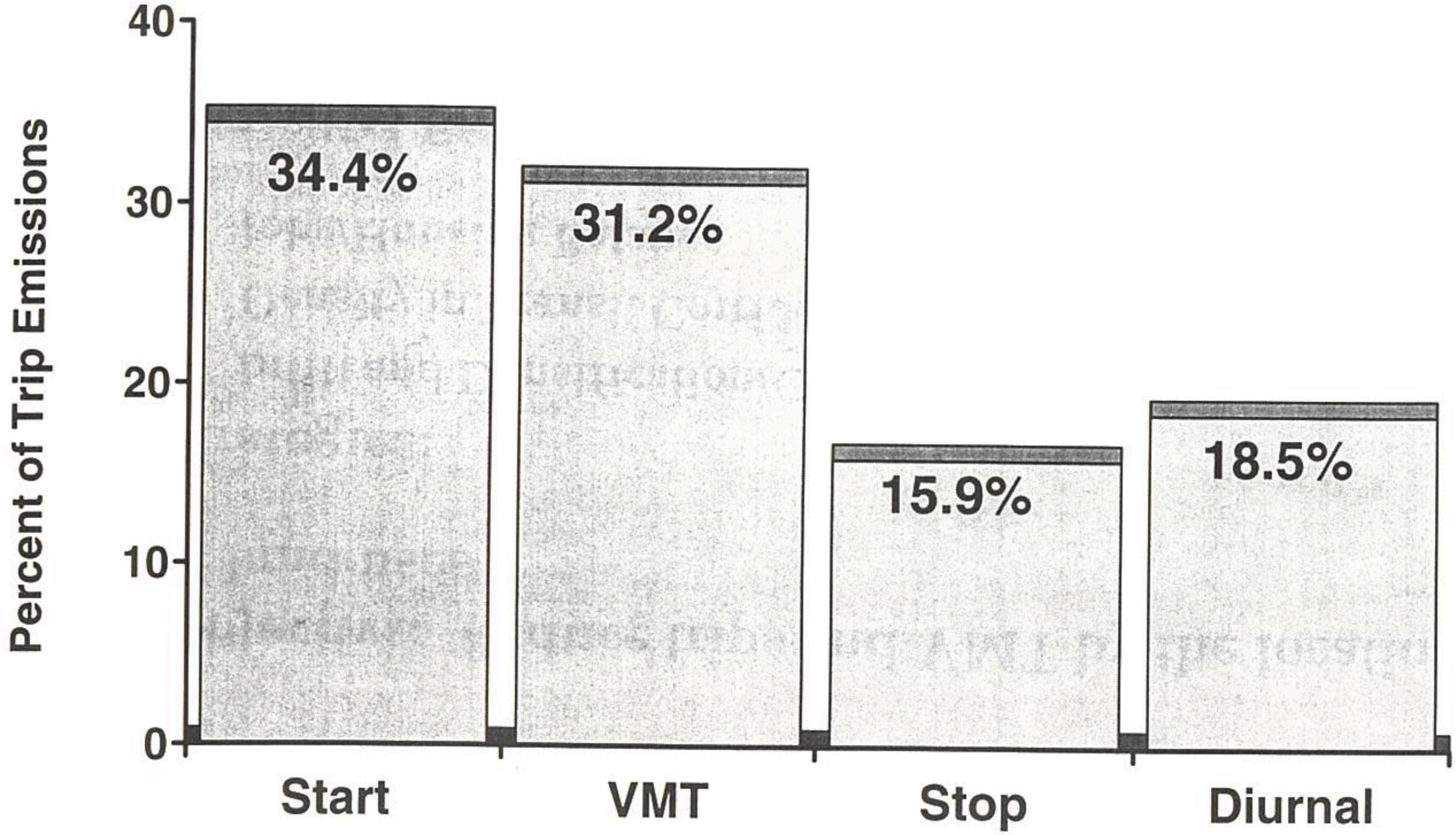
National Trends in Vehicle Emissions (VOC)



National Trends in Population, Vehicles, and VMT



Hydrocarbon Emissions by Type



Typical: 20 mile round trip, light duty automobile

Regional Strategies

- Objective: Reduce trips and VMT by the location of land uses
- Strategies:
  - Infill and Densification/Core Orientation
  - Density in Transit Corridors
  - Jobs/Housing Balance
- Potential Effectiveness:
  - 5% to 10% increase in transit use
  - 10% to 20% reduction in auto use
  - Effects of Jobs/Housing Balance not Clear

Site Design

- Objectives: Reduce trips and VMT by location of uses and facilities within a site
- Strategies:
  - Transit-Oriented Design
  - Pedestrian-Oriented Design
  - Mixed-Use Development
- Potential Effectiveness:
  - Supportive of Regional Strategies
  - 20% to 25% reduction in auto travel within development
  - Pleasant environment can double distance people will walk

Conclusions

- Land-Use Strategies Should Support Transportation Strategies
- Regional Strategies Appear to be Most Effective
- Site Design Strategies Can Support Regional Strategies
- A Variety of Mechanism are Available to Implement Strategies

LAND-USE STRATEGIES TO IMPROVE AIR QUALITY

Overview

Air Pollution is a serious concern in the five-county Philadelphia metropolitan area of Pennsylvania. Air pollution can result in significant health problems for a region's population and result in a significant economic loss as well. Without effective strategies to reduce the amount of pollutant emissions per person trip, significant constraints on the economic growth of the region may result. The Transportation Conformity regulations of the current Clean Air Act require that the long range plan (LRP) for transportation and the transportation improvement program (TIP) within each metropolitan area be consistent with the state implementation plan (SIP) for meeting the national ambient air quality standards. If it cannot be demonstrated that the LRP and the TIP will result in a level of transportation activity that meets the air quality standards by the prescribed target date, federal funding for transportation projects may be withheld from the region.

In most metropolitan areas, motor vehicle emissions account for roughly half of the pollutant emissions that produce ozone and eighty percent of the carbon monoxide emissions that result in exceedances of the standards. Because of their significant contribution, motor vehicles have been the target for significant emission reduction in non-attainment areas. A broad range of technological and demand management measures have been explored to reduce the pollutant emissions per vehicle trip or to reduce the amount of vehicle use needed to meet the mobility requirements of a region. Recently, more significant attention has been given to strategies that reduce emissions through land-use control or site design.

The nature of the land use in a region is clearly a significant determinant of the amount and nature of travel within a region, and the strategies of interest are those that result in substitution of non-vehicular modes (walk or bicycle) for vehicular modes, greater use of transit or ride sharing over use of single-occupant vehicles or reduction of the length of automobile trips. The land-use strategies given frequent consideration are of two general types:

- Regional Strategies - those that influence where within a region new development or redevelopment occurs. Regional strategies include:
  - Infill and Densification
  - Density in Transit Corridors
  - Jobs/Housing Balance
- Site-design Strategies - those that result in greater use of non-motorized modes, transit or ridesharing by the nature of how specific sites or small sub-areas are developed. Site-design strategies include:

- Transit-Oriented Design
- Pedestrian-Oriented Design
- Mixed-Use Development

While many of the transportation control measures considered for emissions reduction focus on reducing work-related travel which constitutes only about one-third of daily urban travel, land-use and site-design strategies potentially impact all trips to or from an area affected by a strategy.

The Nature of the Air Quality Problem

The potential effectiveness of alternative land-use strategies in reducing motor vehicle emissions to some degree is dependent upon the nature of the air quality problem in a region. The most serious problem affecting the Philadelphia area is ozone. Ozone is a colorless gas that results from the combination of volatile organic compounds (VOCs) and oxides of nitrogen (NO_x) in the presence of sunlight and heat. Because of the need for sunlight and heat for the formation of ozone, it is almost exclusively a problem during the summer months. Because the process by which ozone is formed in the presence of sunlight and heat, it is also generally a regional problem that is influenced by the aggregate VOC and NO_x emissions in a region and not a "hot spot" problem that results from the emissions in a finite area.

In contrast to ozone, carbon monoxide (CO) and particular matter less than 10 micrometers in size (PM_{10}), require no additional chemical reaction, but represent harmful pollutants as they are emitted from a vehicle. As a result, both CO and PM_{10} tend to be "hot spot" air quality problems. Fortunately neither CO or PM_{10} currently represent air quality problems in the Philadelphia area based on existing air quality standards.

Where ozone is an air-quality problem, ozone production can generally be reduced by reducing the production of either VOC or NO_x emissions. The level of one or the other will generally determine the amount of ozone produced but generally not both, at least within certain limits of desired reduction in ozone concentration.

The Connection Between Land-use Strategies and Emission Reductions

Land-use strategies can be effective in reducing pollutant emissions in three ways:

1. by completing eliminating some share of vehicular trips
2. by reducing the vehicle miles traveled
3. by reducing idling and travel at very low speeds caused by congestion

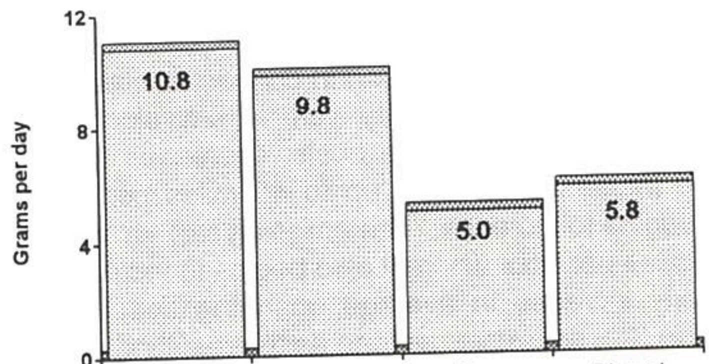
The value of eliminating vehicle trips rather than just reducing VMT or eliminating congestion can be illustrated by a sample calculation using average emission rates for a prototypical round trip for work. The twenty-mile round trip at an average speed of 40 miles per hour would generate roughly 30 grams of VOC emissions under existing emission controls as illustrated in Figure 1. Of this amount, however, less than one-third would be associated with the vehicle miles traveled. Fifty percent of the emissions of VOC result from the trip being made - the starting of the vehicle or evaporative emissions after the vehicle is parked. The remaining one-sixth results from diurnal emissions that occur whether the vehicle is driven or not. Strategies that are aimed at reducing VMT or increasing operating speed in congested areas can, at best, influence only one-third of the emissions of VOC (Loudon and Dagang 1993).

The potential value of increasing speed in congested areas for emission reduction is illustrated by the example light-duty vehicle emission rates in Figure 2. The emission rate, on a grams-per-mile basis, decreases for both VOC and NO_x as average speed increases, at least up to 40 miles per hour. Over 40, the NO_x emission rate begins to increase. The emission rate for VOC continues to decrease until about 50 miles per hour where it also begins to increase. These emission rates suggest that any increase in average operating speed in congested areas can reduce VOC and NO_x emissions as long as the resulting speed is less than 40 miles per hour.

In many cases, land-use strategies will have benefits of all three types described above: trip reduction, VMT reduction and speed increase. Ones that eliminate vehicular trips by allowing more people to ride share, use transit, bicycle or walk rather than drive alone will usually result in a decrease in VMT and an increase in average operating speed as a result of having fewer vehicles on the roadway network. This is not always the case, however, and the results that will ultimately be achieved cannot always be predicted.

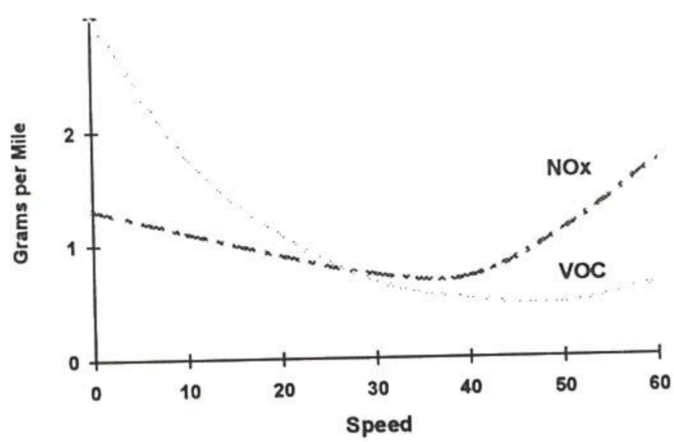
A regional strategy that focuses on employment in a central core area and housing along radial corridors that are well-served by transit may result in fewer overall vehicular trips than a land-use strategy that seeks a high level of jobs/housing balance throughout all parts of the region. While producing a higher share of trips by transit, the core-oriented land-use pattern may result in equal or higher overall VMT, because those who do not rideshare or use transit may have longer trip lengths on average than the land-use patterns with greater jobs/housing balance. The jobs/housing balance strategy may result in more work trips being made by bicycle or walk and may result in shorter average commute trip length but may also result in significantly fewer transit or rideshare trips because of the difficulty of providing a high level of transit service in an area with short trips and low trip destination density. The result may be higher emissions because of the greater number of vehicle starts.

Figure 1
Volatile Organic Compound (VOC) Emissions by Type



Example: 20 mile round trip, light duty automobile

Figure 2
Relationship of Emission Rate to Speed



There is also no guarantee that balancing the supply of jobs and housing in a geographic sub-region will result in shorter trip lengths. People do not necessarily take the job closet to their home.

Evidence of the Effectiveness of Land-use Strategies

There is little direct evidence that land-use strategies are effective in reducing pollutant emissions or in reducing the frequency by which an air quality standard is exceeded in a metropolitan area. The availability of direct evidence in limited because:

1. There has been little use of land-use strategies with the specific intent of improving air quality.

2. Most land-use strategies require many years to achieve desired objectives.

3. There are generally no systematic evaluation efforts to assess the effectiveness of individual land-use strategies.

Lacking direct evidence of the effectiveness of specific strategies, some generalizations are possible from "cross-sectional" analyses that compare the trip-making behavior of two or more areas with significantly different land-use characteristics. The following evidence is available from two extensive reviews of the literature on transportation and land-use strategies (JHK & Associates 1995 and Parker 1994).

Infill and Densification

Infill and Densification emphasize continued redevelopment of older and higher-density portions of a metropolitan area. Such parts of a metropolitan area generally are better served by the regional transit system, are more likely to have a well-developed pedestrian system and are more likely to have a mixture of compatible residential and commercial uses that result in the replacement of vehicular trips with walk trips. In a study of San Francisco Bay Area communities, Holtzclaw (1990) found that a doubling in residential density was associated with 20 to 30 percent less VMT per household. Dunphy and Fisher (1994) examined data from the 1990 National Personal Transportation Survey and also found that VMT per household decreased consistently with increasing residential density except at the lowest density levels (less than 2,700 persons per square mile).

Density in Transit Corridors

This strategy represents an effort to promote and facilitate higher-density land uses around high-capacity rapid transit stations. There is consistent evidence that transit use is higher among residential employment centers located closer to rail transit stations. Cervero (1993b) found that transit use among residents near BART stations in the San Francisco Bay Area was as high as 30 percent while those located further from BART ranged from only a few percent to 15 percent. JHK & Associates (1989) found that residential use of transit declines by roughly 0.65 percent for every 100 feet distance from transit and office use declines by about 0.75 percent for every 100 feet of distance. In an overall study of the relationship between land-use density and transit use, Pushkarev and Zupan (1977) found that transit share triples for each doubling in density in a transit corridor.

Job/Housing Balance

The objective of a job/housing balance is to reduce average commute trip length by locating employment in communities proportionate to the residence of the work force. This approach is in contrast to a core area focus of employment with bedroom communities around the periphery of the metropolitan area. Because most urban transit systems are more efficient in service to a core-oriented employment, however, job/housing balance can result in shorter average trip lengths for commute trips but with a higher auto use share. Quantitative studies on the effectiveness of job/housing balance are limited and present contradictory conclusions. Cervero (1993b) concluded that a job/housing balance was associated with a 3 to 5 percent increase in travel by walking, bicycling and transit. In contrast, Giuliano (1990) concluded that job/housing balance did not produce any quantifiable travel-related benefits.

Transit-Oriented Design

Transit-oriented design is a deliberate attempt to facilitate access to transit services from residential, commercial, or mix-use developments. The design concept emphasizes the location of homes and businesses within comfortable walking distance of transit services and emphasizes the design of pedestrian facilities to accommodate the walk trip. Several major studies comparing the travel characteristics of a variety of communities have found that transit-oriented design can significantly increase the use of transit in a neighborhood. Bacon et al. (1993), in a comparison of two neighborhoods in the San Francisco Bay Area, found that the one with the most transit-oriented design had a 20 percent lower drive-alone share for commute trips and fewer of the rail transit users drove to the rail station. Freidman et al. (1992), who also analyze Bay Area neighborhoods, found that transit-oriented neighborhoods had 25 percent fewer auto-driver trips than more auto-oriented neighborhoods.

Cervero et al. (1993a), in a matched-pair analysis of work trips in pre- and post-war neighborhoods in San Francisco and Los Angeles, found that transit-oriented neighborhoods had a slightly higher transit mode share in Los Angeles (1.3 percent) and a more significant increase in mode share in San Francisco (5.1 percent). The paired comparison controlled for income, density and transit service.

Pedestrian-Oriented Design

Pedestrian-Oriented Design encompasses three main design concepts:

- Location of land uses to facilitate access by foot
- Provision of sidewalks and other pedestrian amenities to make the walking experience a pleasant one
- Design of the development for maximum connectivity of pedestrian facilities

Recently the traditional or neo-classical neighborhood design concept has received new popularity for residential development. This generally includes narrower streets, shallower set backs from the streets, mixture of usage, greater connectivity of the collector street system (to improve the walk connection between homes and shopping). The concept has also been combined frequently with higher-density development and greater integration of transit services into the development design. Untermann and Lewicki (1984) found in their research that a pleasant and interesting environment can double the distance that people are willing to walk. In a study of how the pedestrian environment affects walking behavior in Portland, Parsons Brinckerhoff Quade and Douglas (1993) found that pedestrian environment is a significant factor in explaining auto use and that pedestrian-oriented design might produce as much as a 20 percent reduction in auto use in a particular development or neighborhood. In studies of interconnected street networks such as a gridded street pattern compared with cul-de-sacs and dead-end streets Friedman et al. (1992) and Kulash (1974) both found that an integrated roadway network resulted in less vehicle miles of travel per household within residential neighborhoods.

Mixed-Use Development

The objective behind mixed-use development is to group compatible uses within the same development. This may include the location of housing, employment, and retail services to reduce the number of trips by residents for commuting or other purposes or it may include the grouping of non-residential uses to accommodate a higher percentage of work-based eating or retail trips without the use of an automobile. In a comparison of mixed-use communities with auto-oriented communities, Ewing (1994) found that the mixed-use communities generated 2.3 to 2.8 vehicle hours of travel a day per household compared to 3.4 vehicle hours of travel for auto-oriented communities. JHK & Associates (1989) found that a mixed-use suburban activity center had 25 percent mid-day walk trips which compared with only 16 percent mid-day walk trips at a more typical auto-oriented suburban center.

Conclusions

The available evidence on the effects of land-use and site-design strategies on travel behavior clearly suggests that when applied in conjunction with a comprehensive program of multimodal transportation alternatives, regional land use and site-design strategies can reduce vehicle emissions by reducing vehicle trips, vehicular miles of travel and the amount of travel under heavily congested conditions. Although the evidence is primarily from cross-sectional studies of neighborhoods and does not clearly differentiate the effects of individual strategies, the evidence consistently suggests that land-use and site-design strategies can be effective elements of an overall approach to mobility enhancement, congestion reduction and air quality improvement.

References

1. Bacon, Vinton, Carolyn Radisch, Tom Wieczorek, Trip Reduction Potential of "Transit Village" Development Pattern, prepared for: Professor Robert Cervero and Dan Solomon, University of California, Berkeley, City Planning 218/Architectu 201; December 6, 1993.

2. Cervero, Robert, Robert Fraizier, Roger Gorham, Lisa Madigan, and Edward Stewart, Transit-Supportive Development in the United States: Experiences and Prospects, prepared for Federal Transit Administration, U.S. Department of Transportation, October 1993.

3. Cervero, Robert, Ridership Impacts of Transit-Focused Development in California, National Transit Access Center (NTrac), University of California, Berkeley, October 1993.

4. Dunphy, Robert T., Kimberly M. Fisher, Transportation, Congestion, and Density: New Insights, Transportation Research Board, 73rd Annual Meeting, Washington, D.C., January 9-13, 1994.

5. Ewing, Reid, Padma Haliyur and G. William Page, Getting Around a Traditional City, A Suburban PUD, and Everything In-Between, Transportation Research Board, 73rd Annual Meeting, January 1994.

6. Friedman, Bruce, Stephen P. Gordon, John B. Peers, The Effects of Neo-Traditional Neighborhood Design on Travel Characteristics, Fehr & Peers Associates Inc., Lafayette, California, July 10, 1992.

7. Giuliano, G., The Planning Institute, School of Urban and Regional Planning, University of Southern California, Jobs Housing Balance and Regional Mobility Research Report, April 1990.

8. Holtzclaw, John, Explaining Urban Density and Transit Impacts on Auto Use, presented by National Resources Defense Council and the Sierra Club to the State of California Energy Resources Conservation and Development Commission, 19 April 1990.

9. Institute of Transportation Engineers, Colorado/Wyoming Section Technical Committee, "Trip Generation for Mixed-Use Developments," ITE Journal, February 1987, pp. 27-32.

10. JHK and Associates, Development-Related Ridership Survey II, prepared for the Washington Metropolitan Area Transit Authority, December 1989.

11. JHK and Associates, Transportation - Related Land-use Strategies to Minimize Motor Vehicle Emissions, prepared for the California Air Resources Board, Sacramento, California, 1995.

12. Kulash, Walter, Traditional Neighborhood Development: Will the Traffic Work? Real Estate Research Corporation, 1990.

13. Loudon, William R. and Deborah Dugang, "Evaluating the Effects of Transportation Control Measures," Transportation Planning and Air Quality II, Proceedings of the National Conference of the American Society of Civil Engineers, New York, 1993.

14. Parker, Terry, California Air Resources Board, The Land-Use Air Quality Linkage, How Land Use and Transportation Affect Air Quality, 1994.

15. Parsons Brinckerhoff Quade and Douglas, Inc. with Cambridge Systematics, Inc. and Clathorpe Associates, The Pedestrian Environment, Volume 4A, prepared for 1000 Friends of Oregon, December 1993.

16. Pushkarev, B., and J. Zupan, Public Transportation and Land-Use Policy, Bloomington, Indiana University Press, 1977.

17. Untermann, Richard, with Lynn Lewicki, Accommodating the Pedestrian: Adapting Neighborhoods for Walking and Bicycling, New York, 1984.